



US011721601B2

(12) **United States Patent**
Kang et al.

(10) **Patent No.:** **US 11,721,601 B2**

(45) **Date of Patent:** **Aug. 8, 2023**

(54) **SEMICONDUCTOR PACKAGE AND METHOD OF MANUFACTURING THE SAME**

(58) **Field of Classification Search**

CPC H01L 23/24
See application file for complete search history.

(71) Applicant: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

(56) **References Cited**

(72) Inventors: **Hyeongmun Kang**, Hwaseong-si (KR); **Jungmin Ko**, Hwaseong-si (KR); **Seungduk Baek**, Hwaseong-si (KR); **Taehyeong Kim**, Suwon-si (KR); **Insup Shin**, Seoul (KR)

U.S. PATENT DOCUMENTS

(73) Assignee: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

9,123,830 B2	9/2015	Nakamura et al.	
9,385,104 B2	7/2016	Tani et al.	
9,564,400 B2	2/2017	Mahnkopf et al.	
9,685,411 B2	6/2017	Chen	
10,153,255 B2	12/2018	Hwang et al.	
2013/0234320 A1*	9/2013	Lu	H01L 25/50 257/737
2015/0130078 A1	5/2015	Hong et al.	
2015/0214207 A1	7/2015	Yoshida	
2017/0338206 A1*	11/2017	Seo	H01L 25/0657

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 122 days.

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **17/095,210**

KR	1020150054551	5/2015
KR	10-1680428	11/2016

(22) Filed: **Nov. 11, 2020**

* cited by examiner

(65) **Prior Publication Data**

US 2021/0210397 A1 Jul. 8, 2021

Primary Examiner — William A Harriston

(30) **Foreign Application Priority Data**

Jan. 6, 2020 (KR) 10-2020-0001579

(74) *Attorney, Agent, or Firm* — F. Chau & Associates, LLC

(51) **Int. Cl.**

H01L 23/24	(2006.01)
H01L 23/31	(2006.01)
H01L 21/56	(2006.01)
H01L 23/538	(2006.01)
H01L 23/00	(2006.01)

(57) **ABSTRACT**

A semiconductor package includes a substrate, a plurality of semiconductor devices stacked on the substrate, a plurality of underfill fillets disposed between the plurality of semiconductor devices and between the substrate and the plurality of semiconductor devices, and molding resin surrounding the plurality of semiconductor devices. At least one of the underfill fillets is exposed from side surfaces of the molding resin.

(52) **U.S. Cl.**

CPC **H01L 23/24** (2013.01); **H01L 21/565** (2013.01); **H01L 23/3107** (2013.01); **H01L 23/5385** (2013.01); **H01L 24/13** (2013.01); **H01L 2924/1434** (2013.01); **H01L 2924/3511** (2013.01)

21 Claims, 19 Drawing Sheets

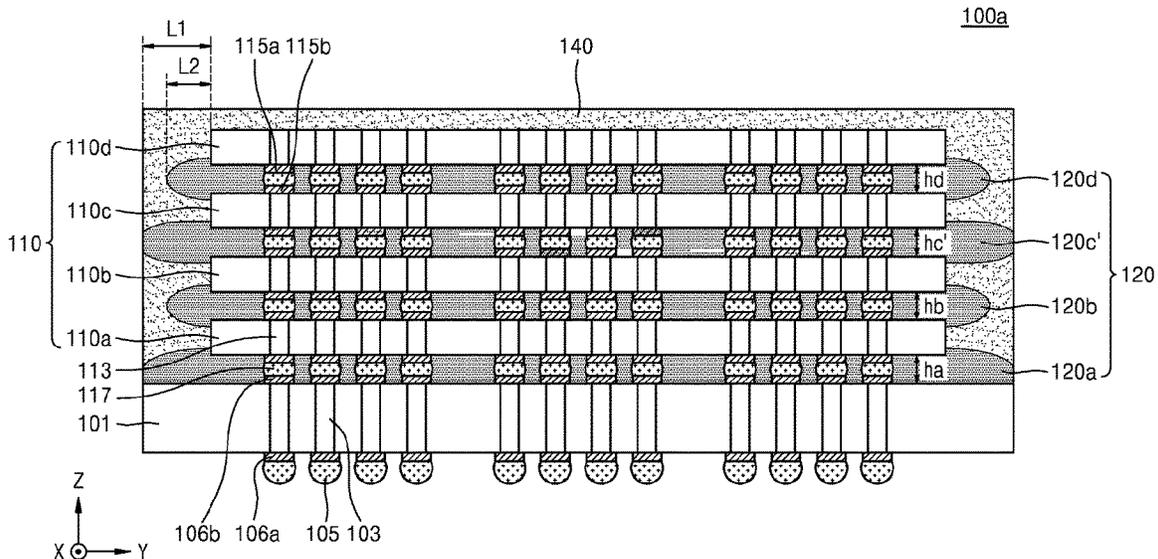


FIG. 1A

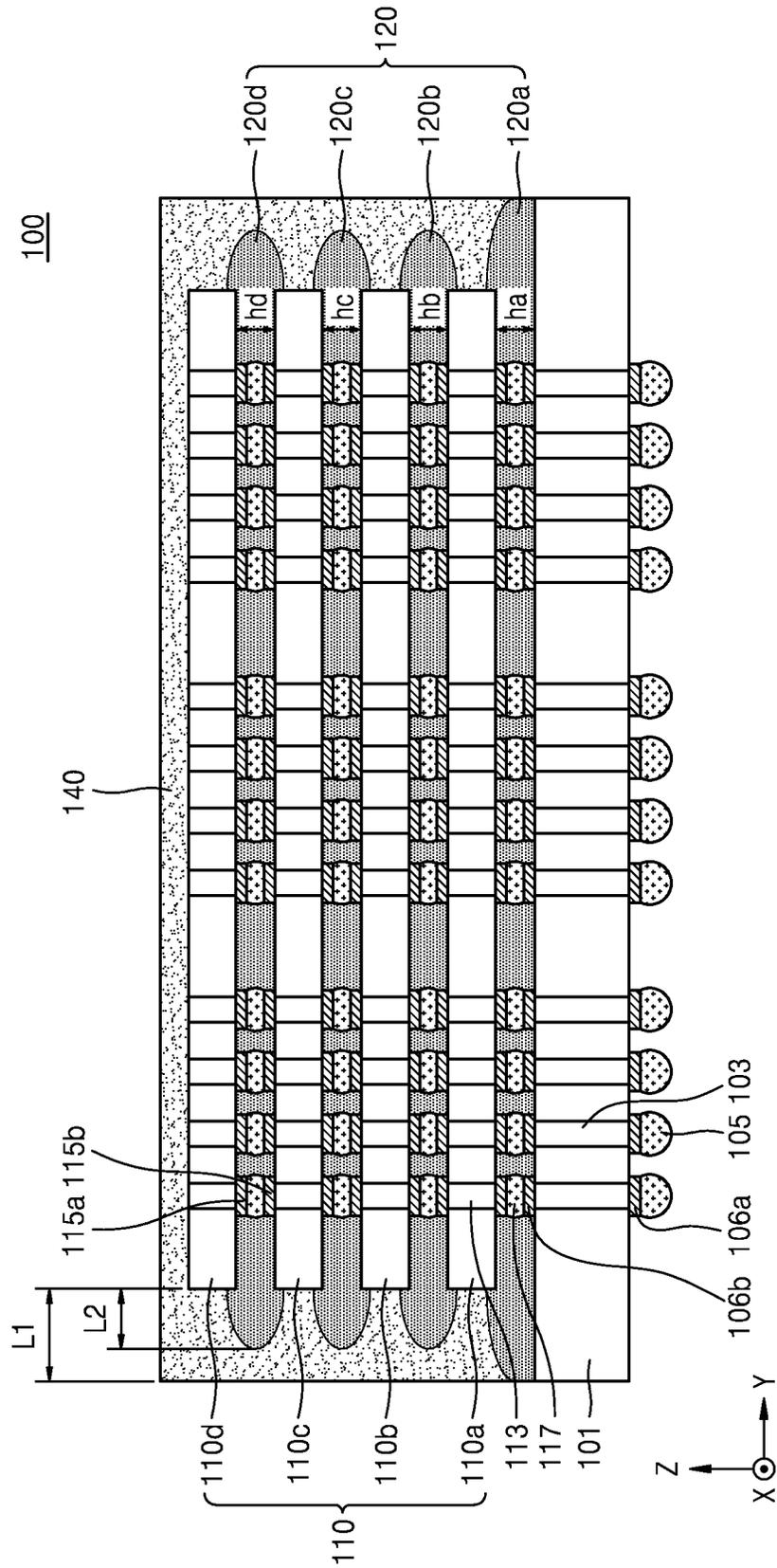


FIG. 1B

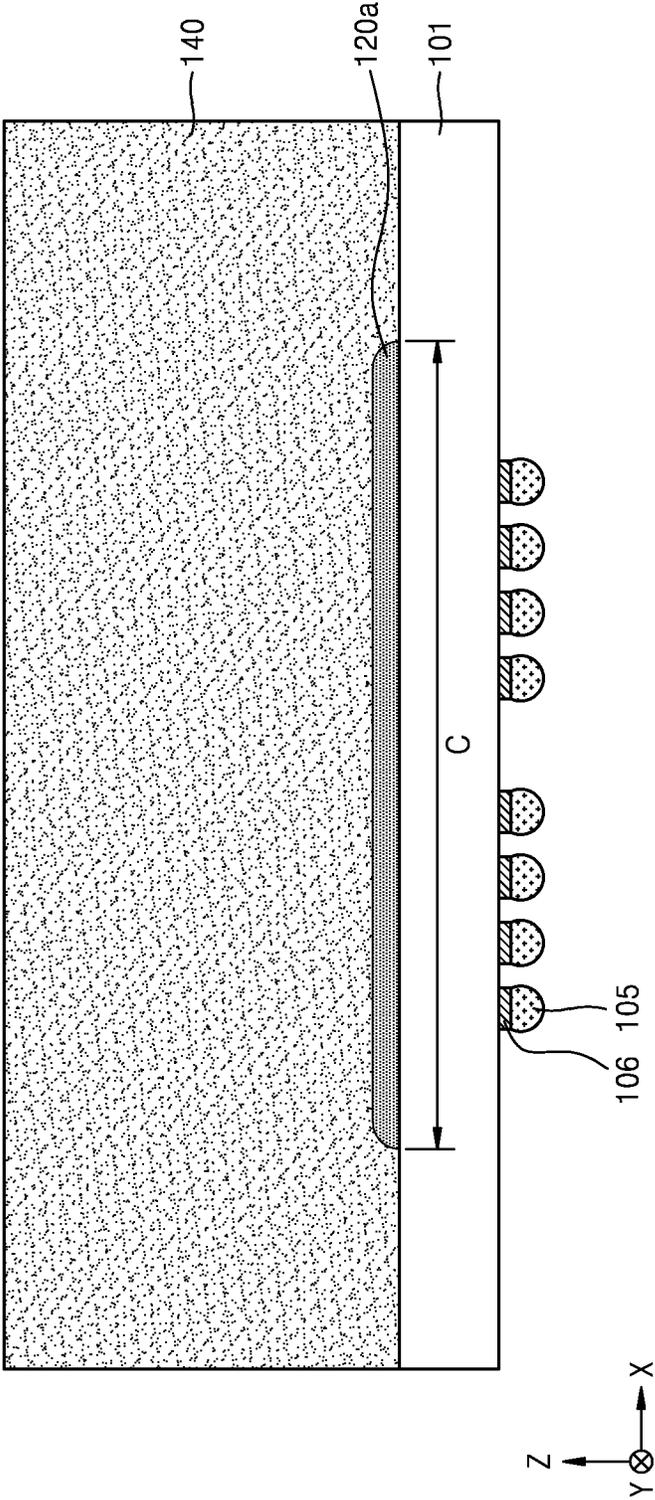


FIG. 2

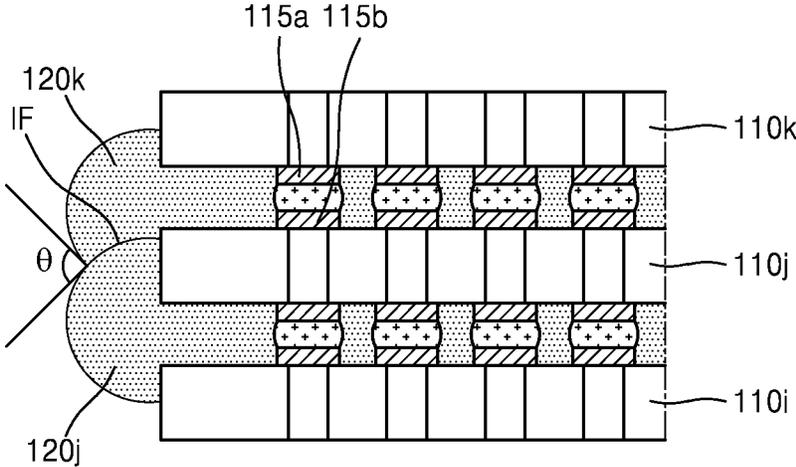


FIG. 3A

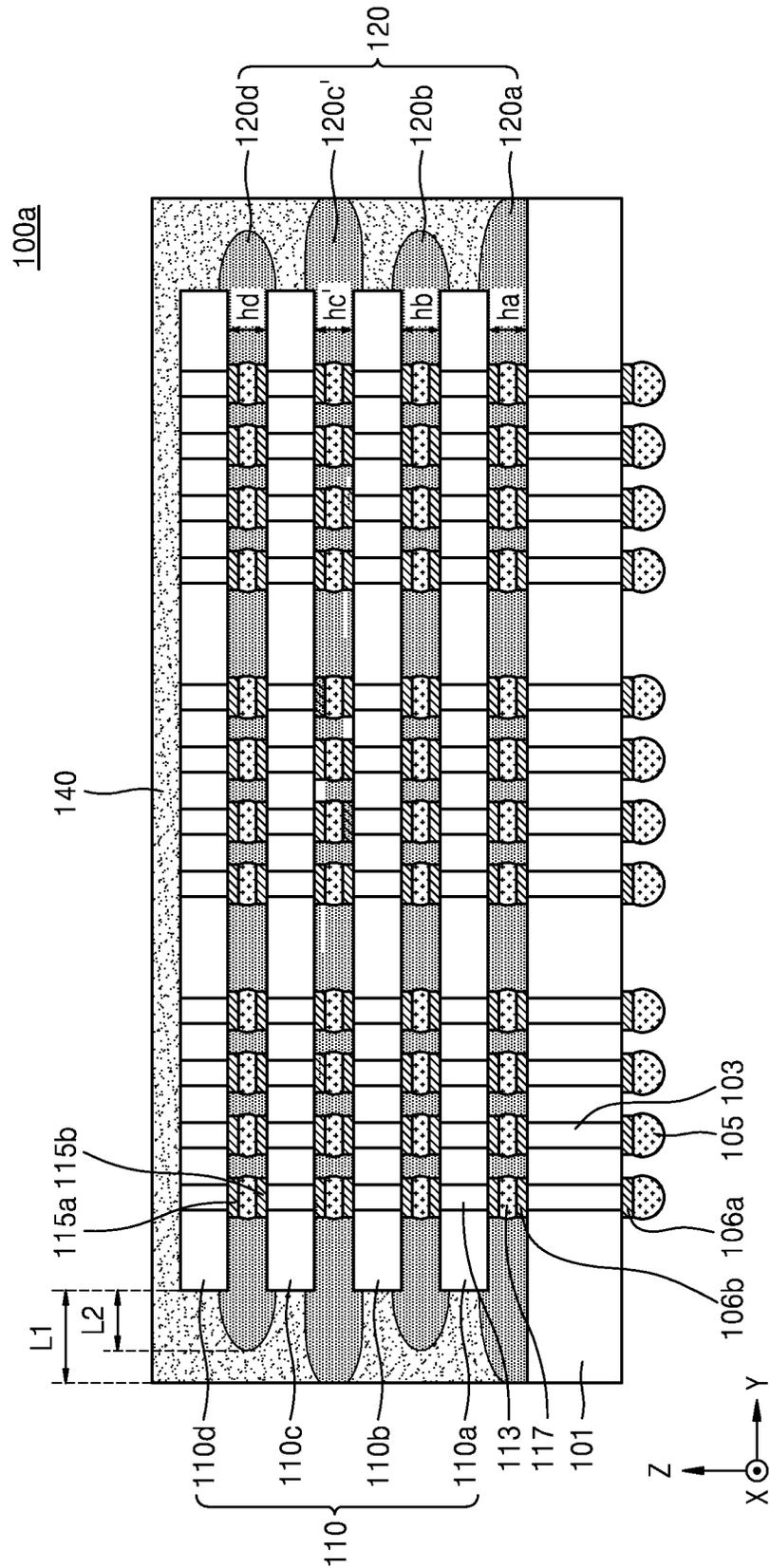


FIG. 3B

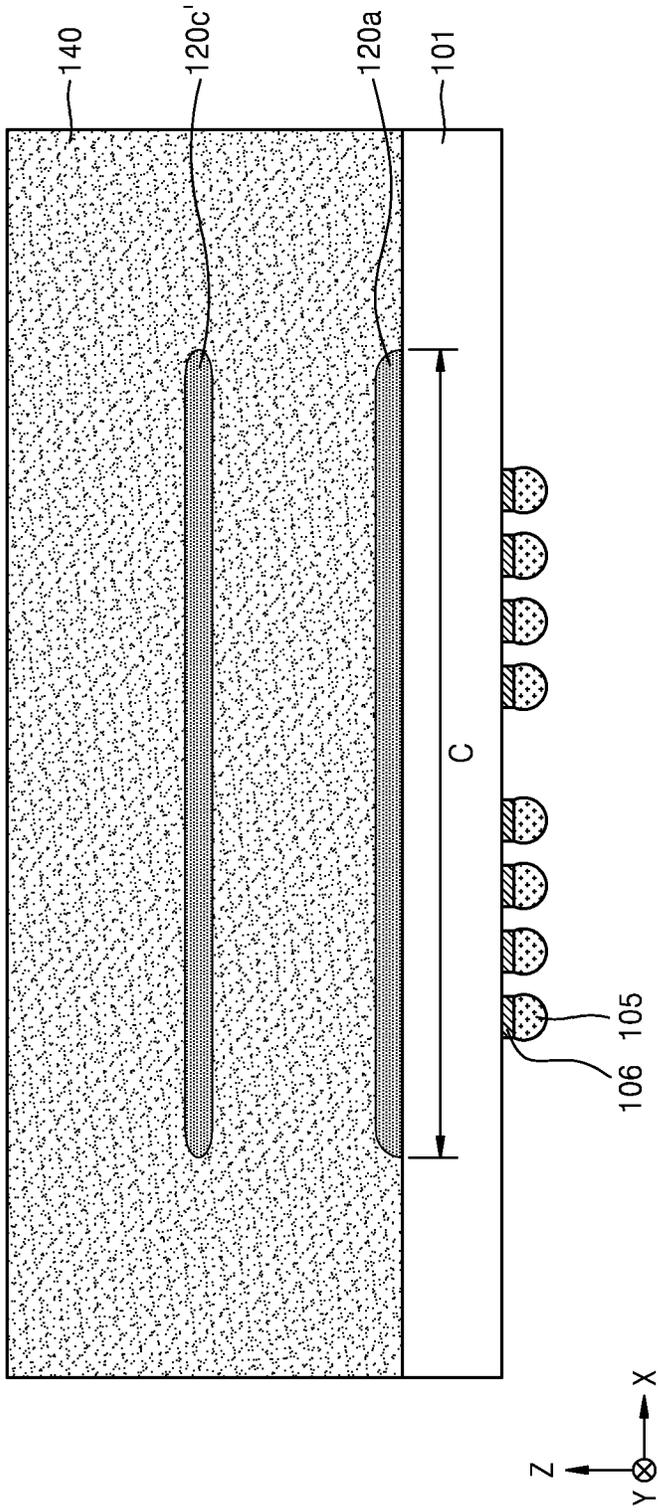


FIG. 4

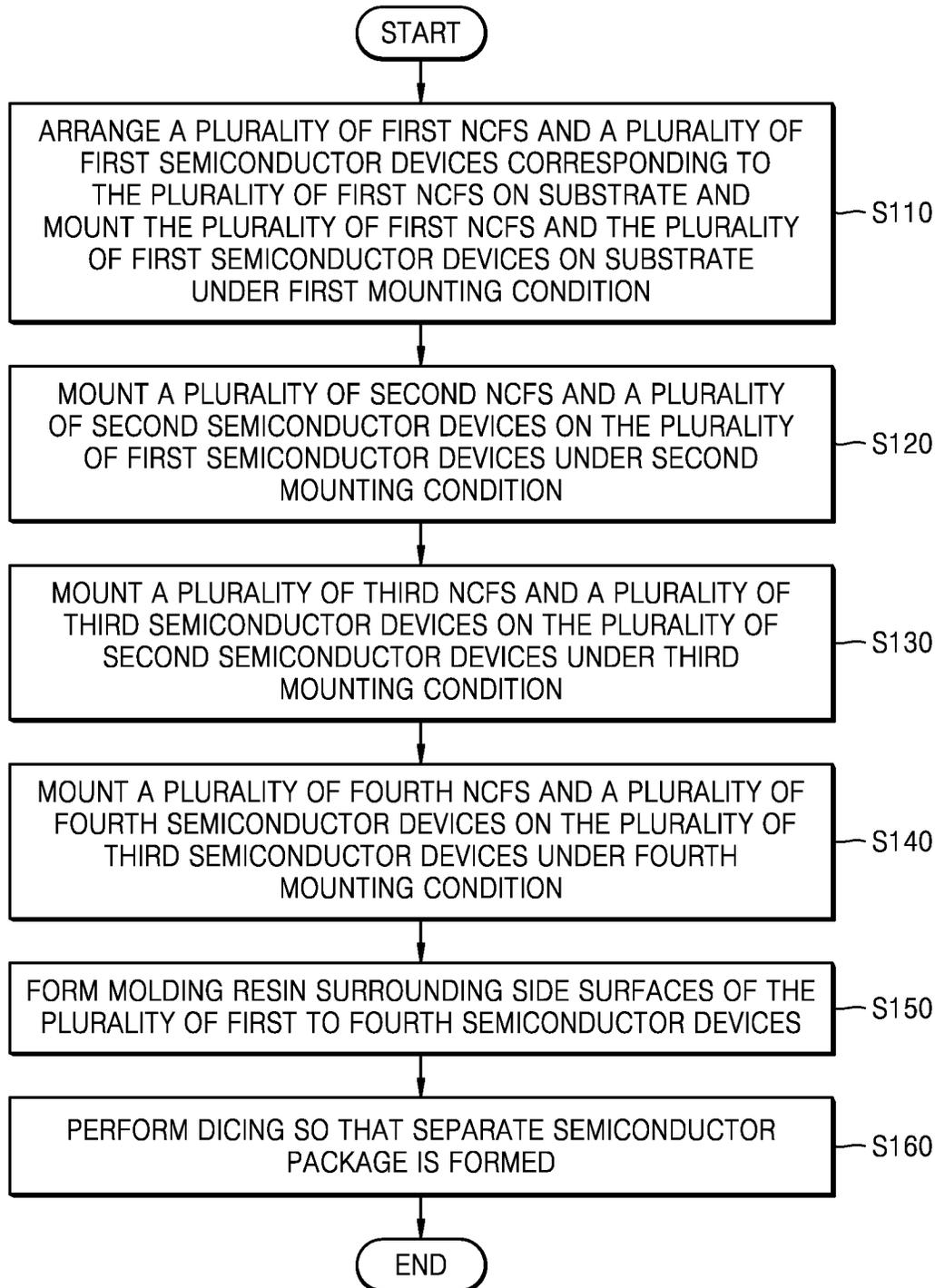


FIG. 5A

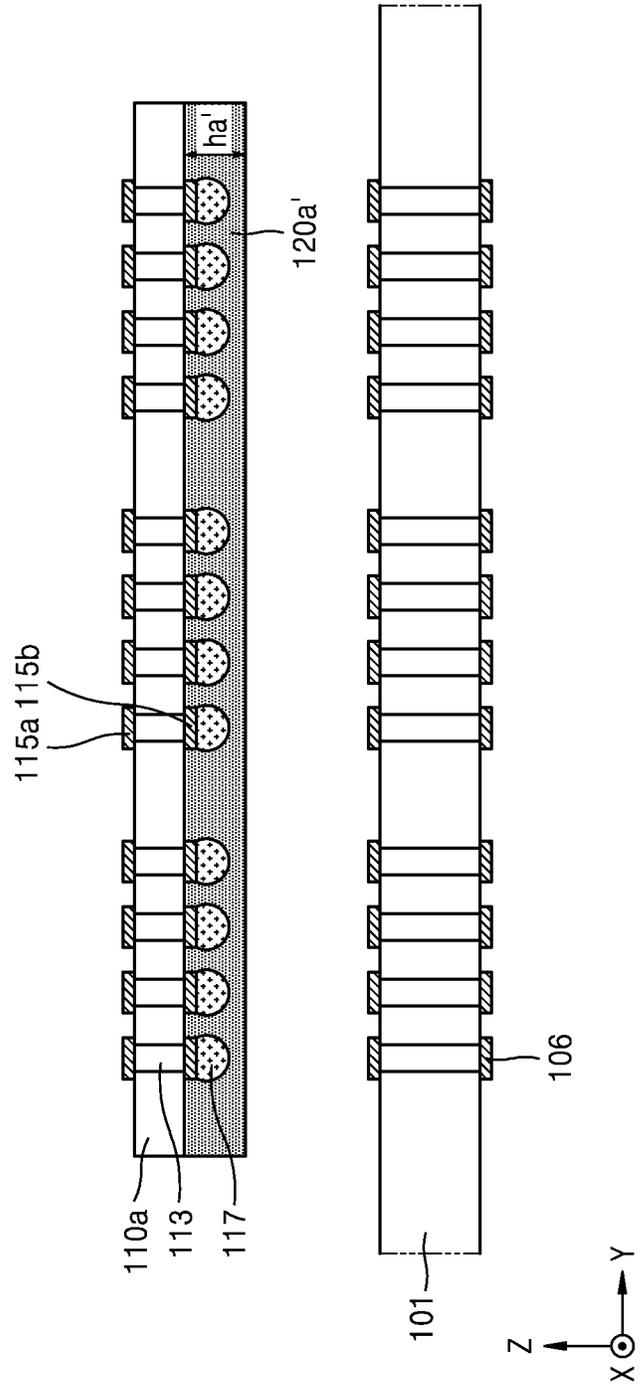


FIG. 5B

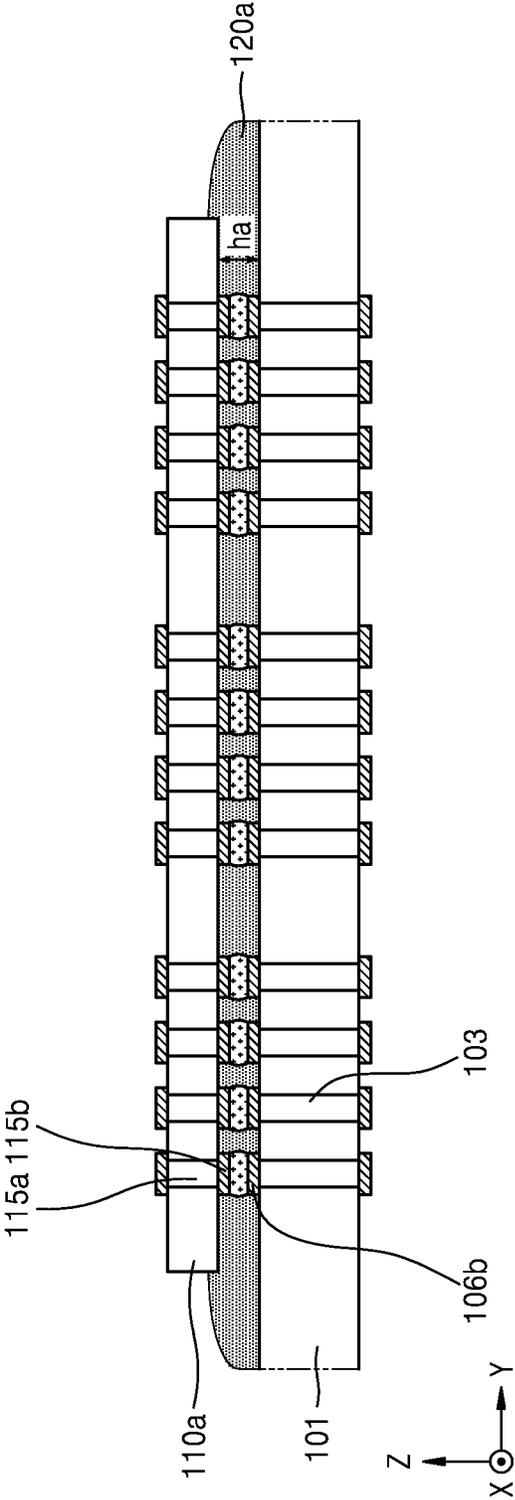


FIG. 5C

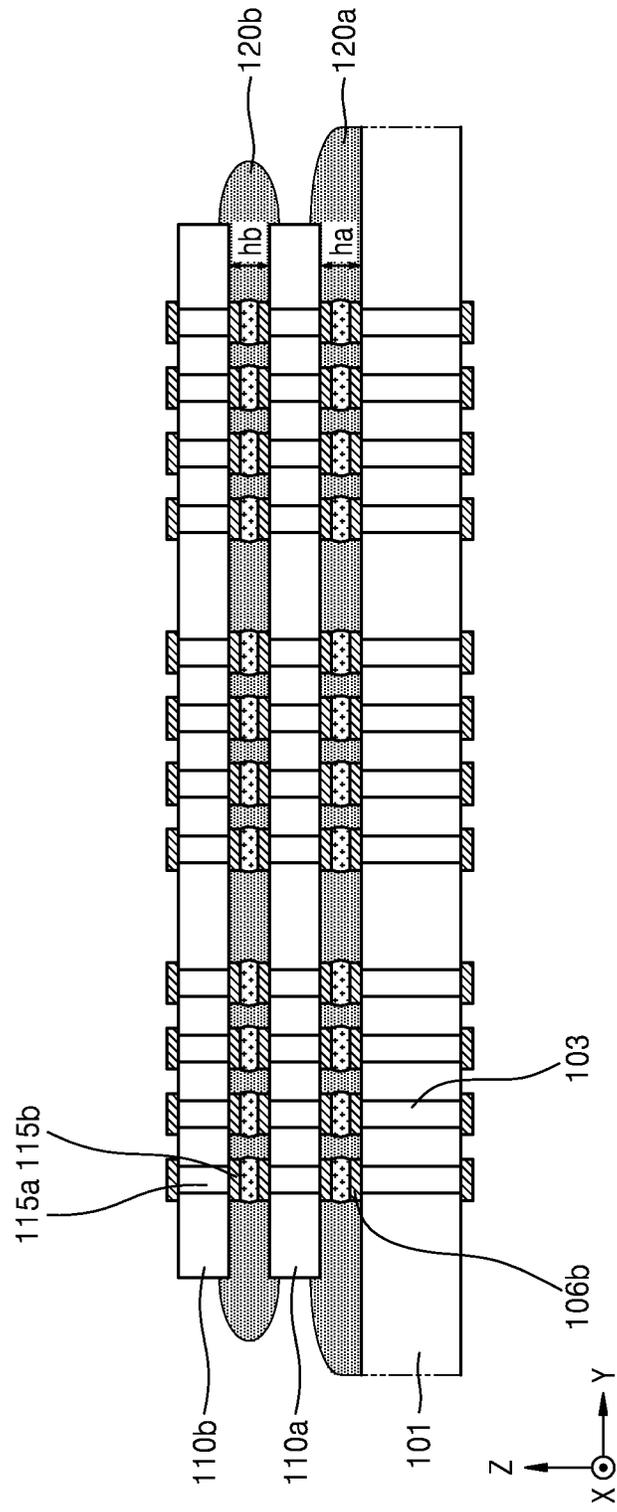


FIG. 5D

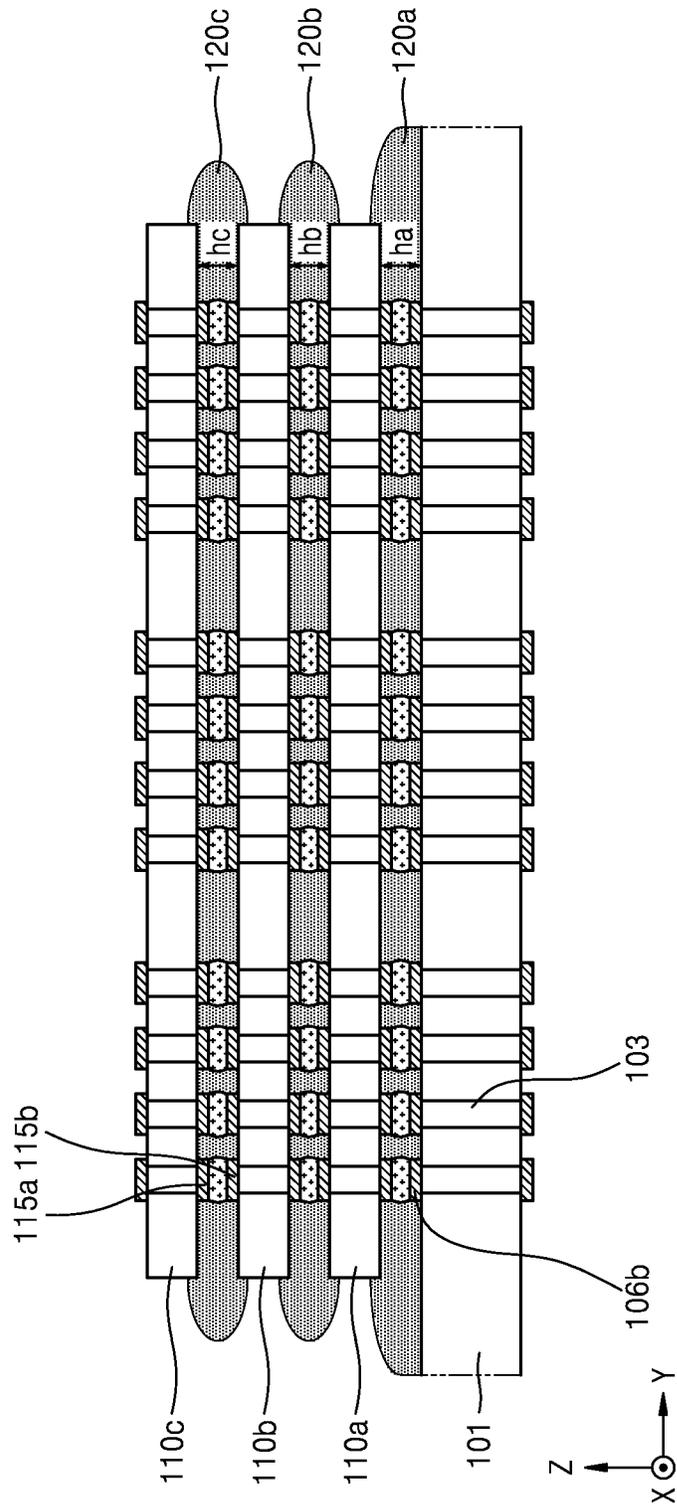


FIG. 5E

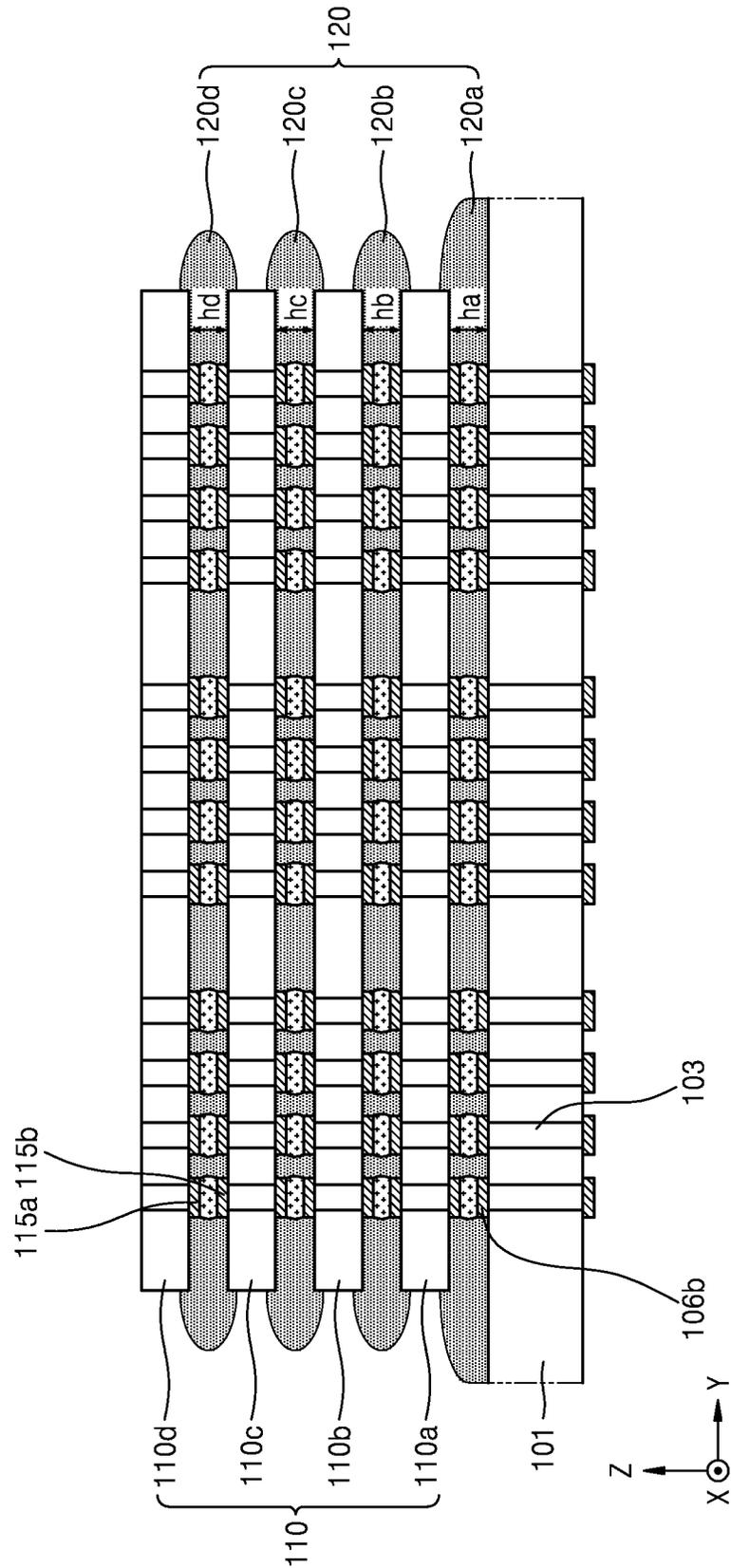


FIG. 5F

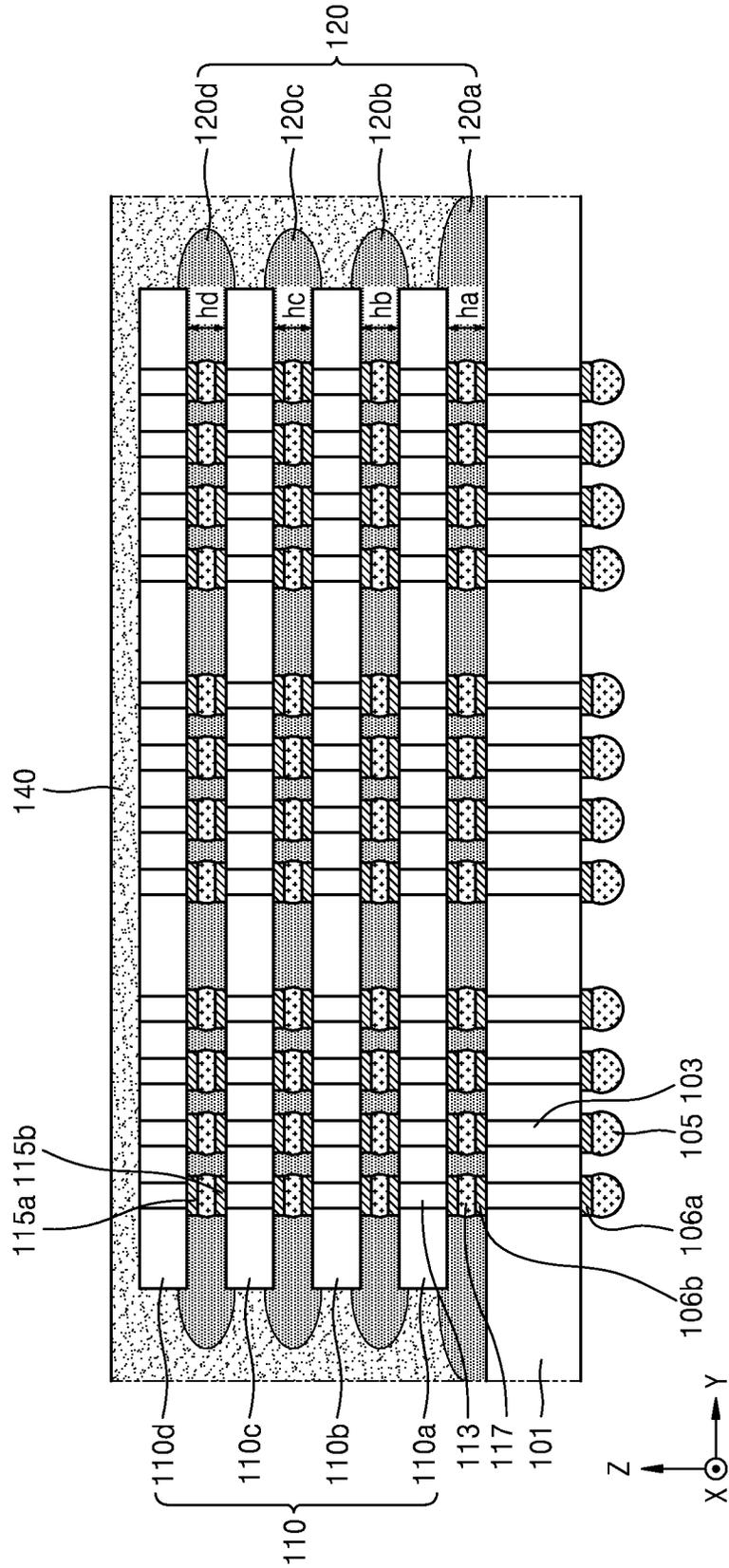


FIG. 5G

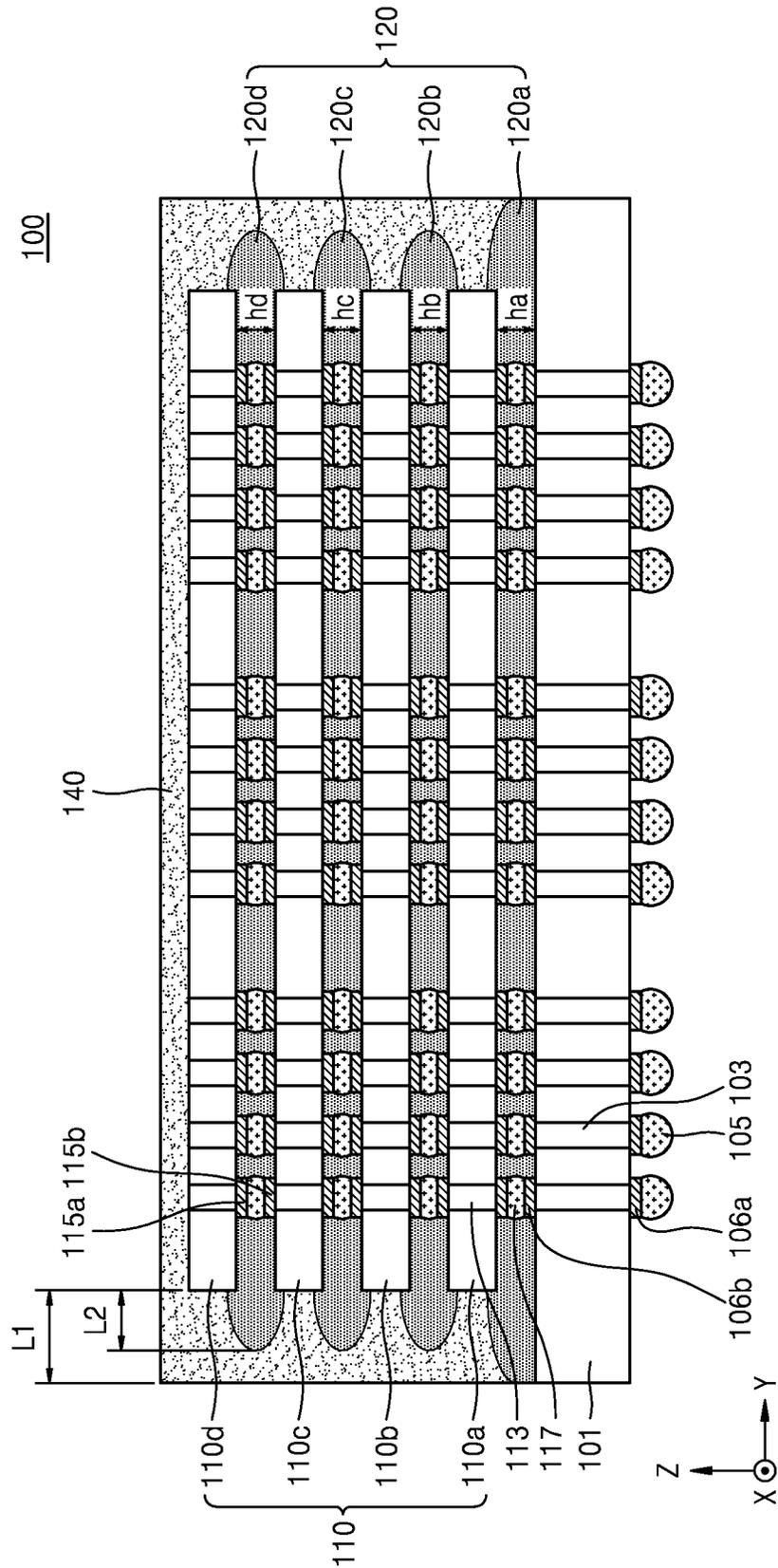


FIG. 6

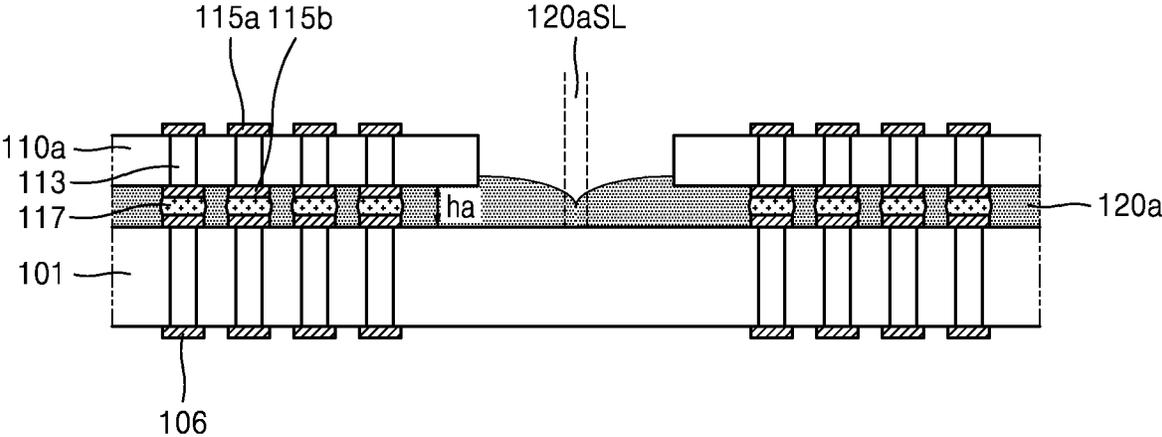


FIG. 7A

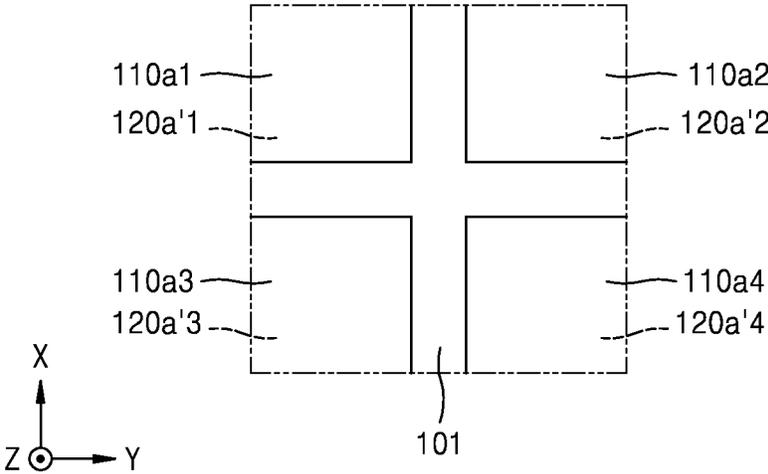


FIG. 7B

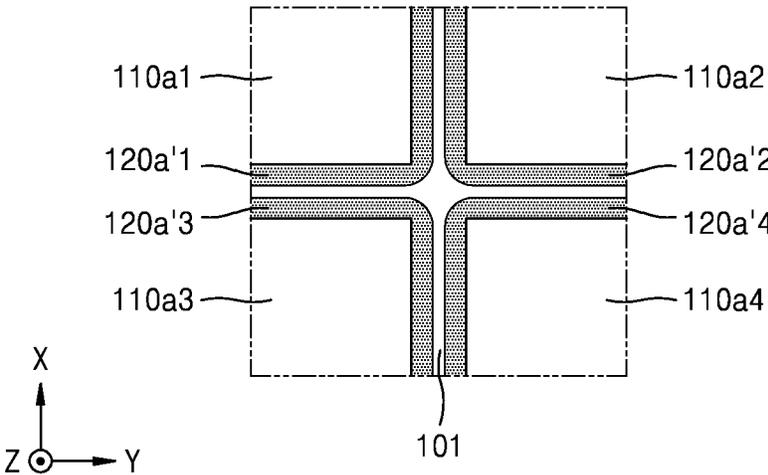


FIG. 7C

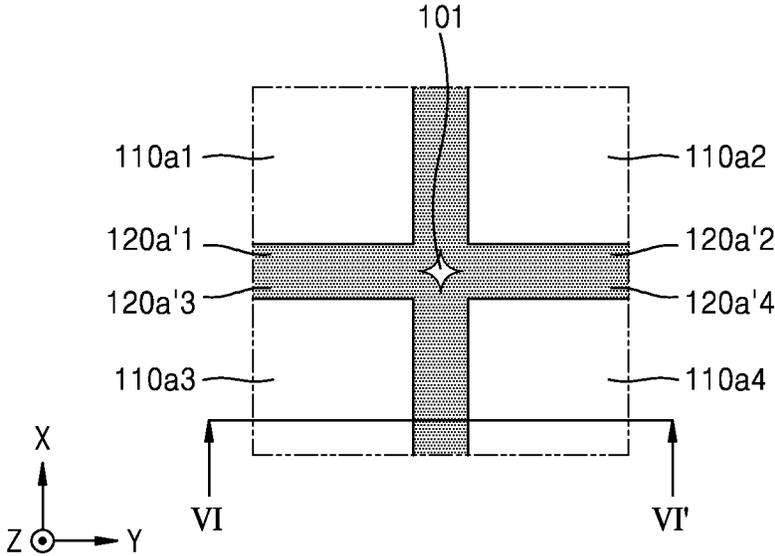


FIG. 7D

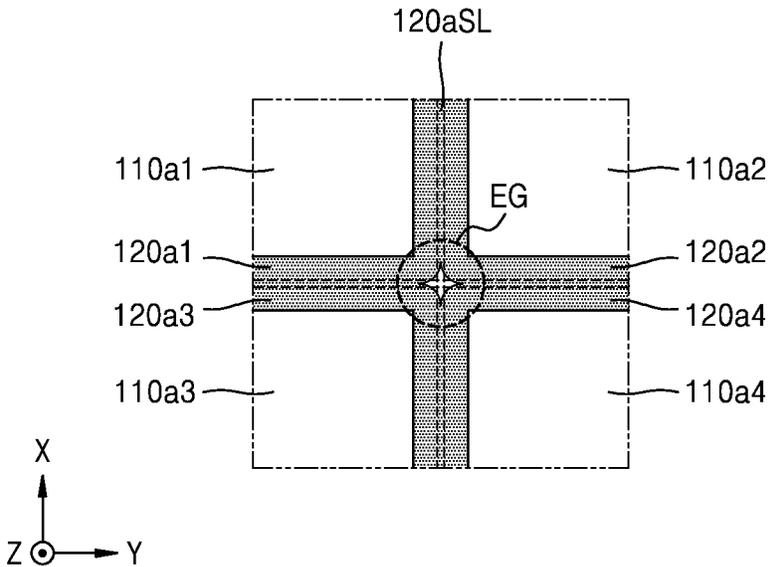


FIG. 8

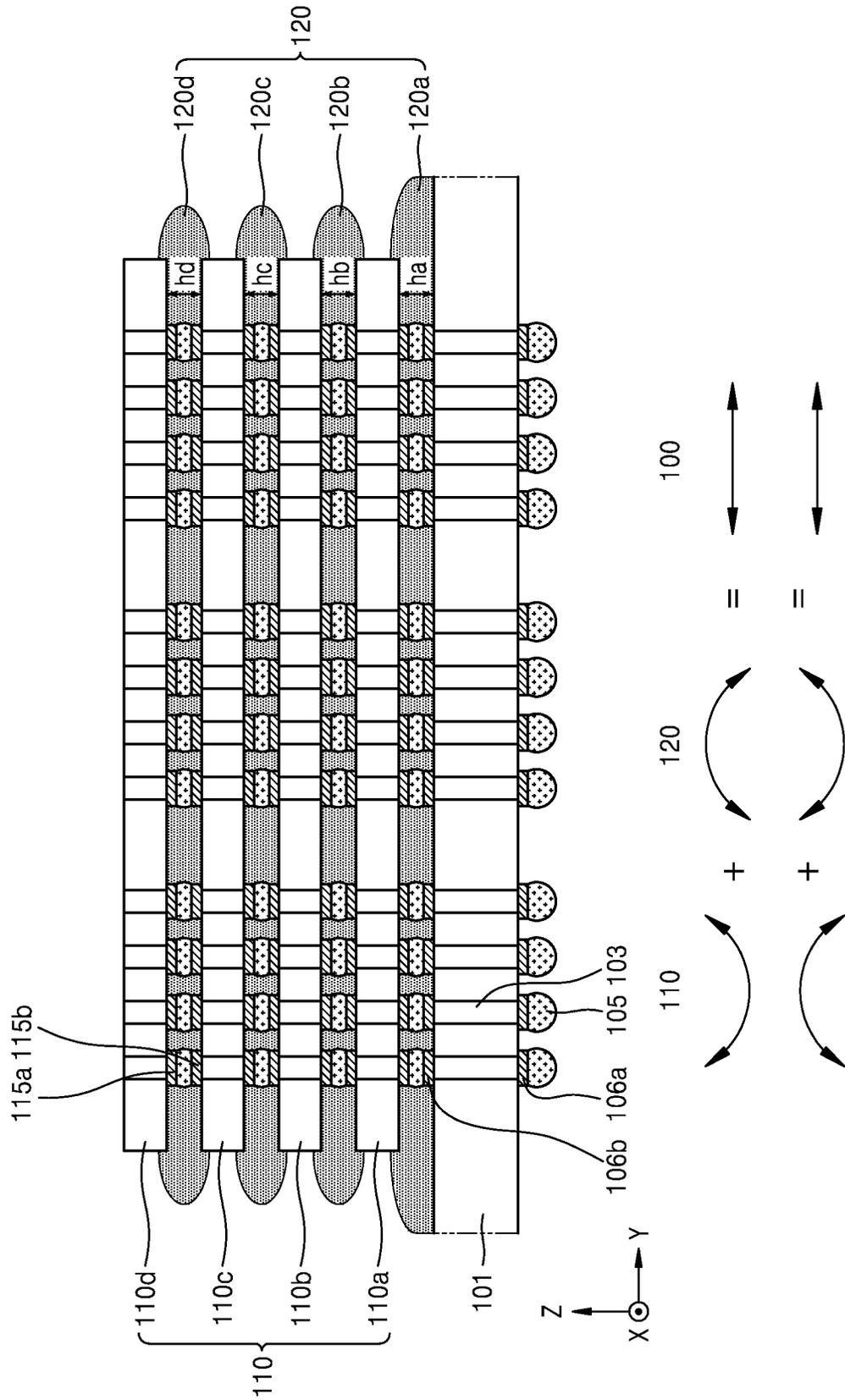


FIG. 9

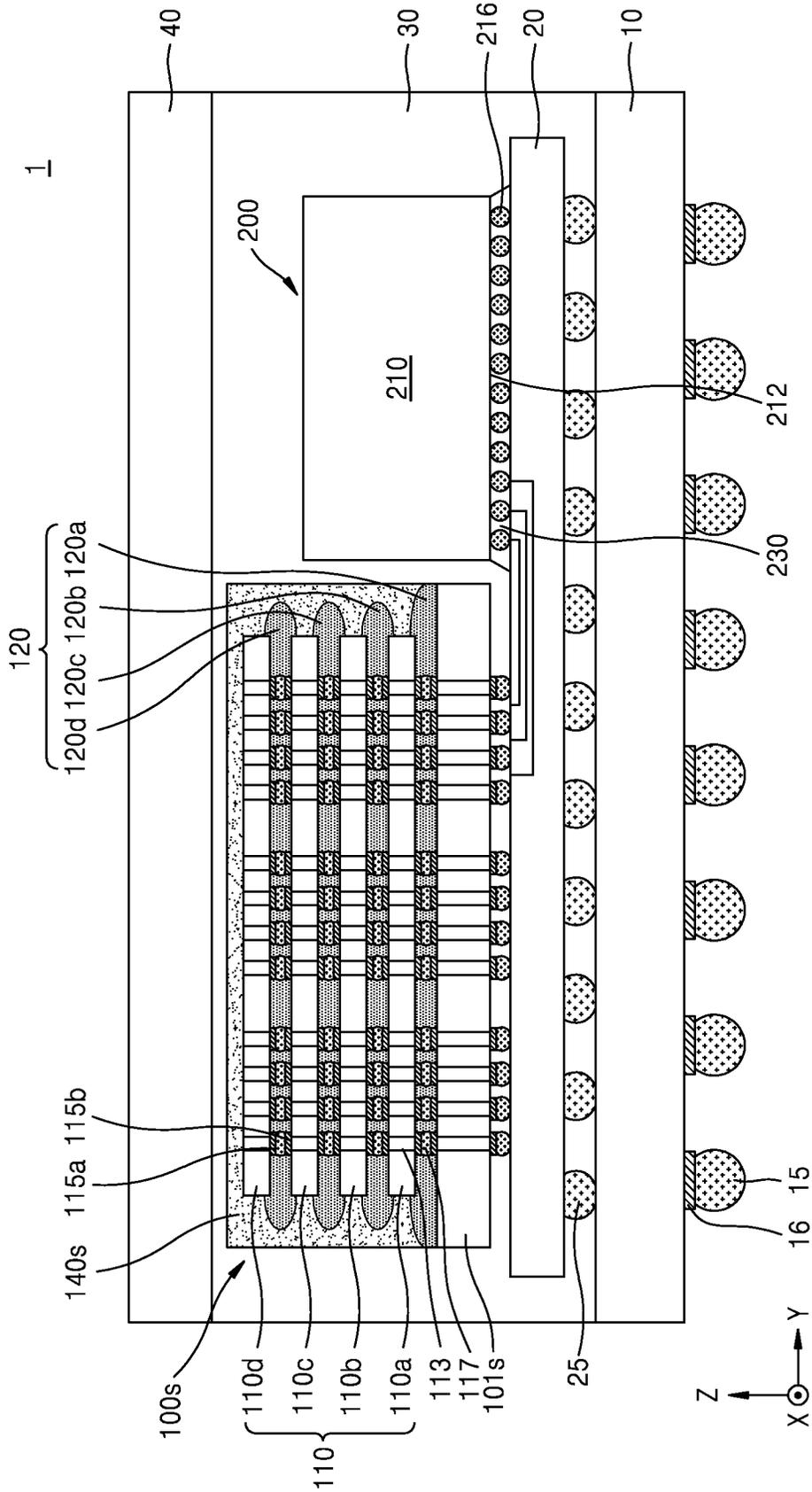
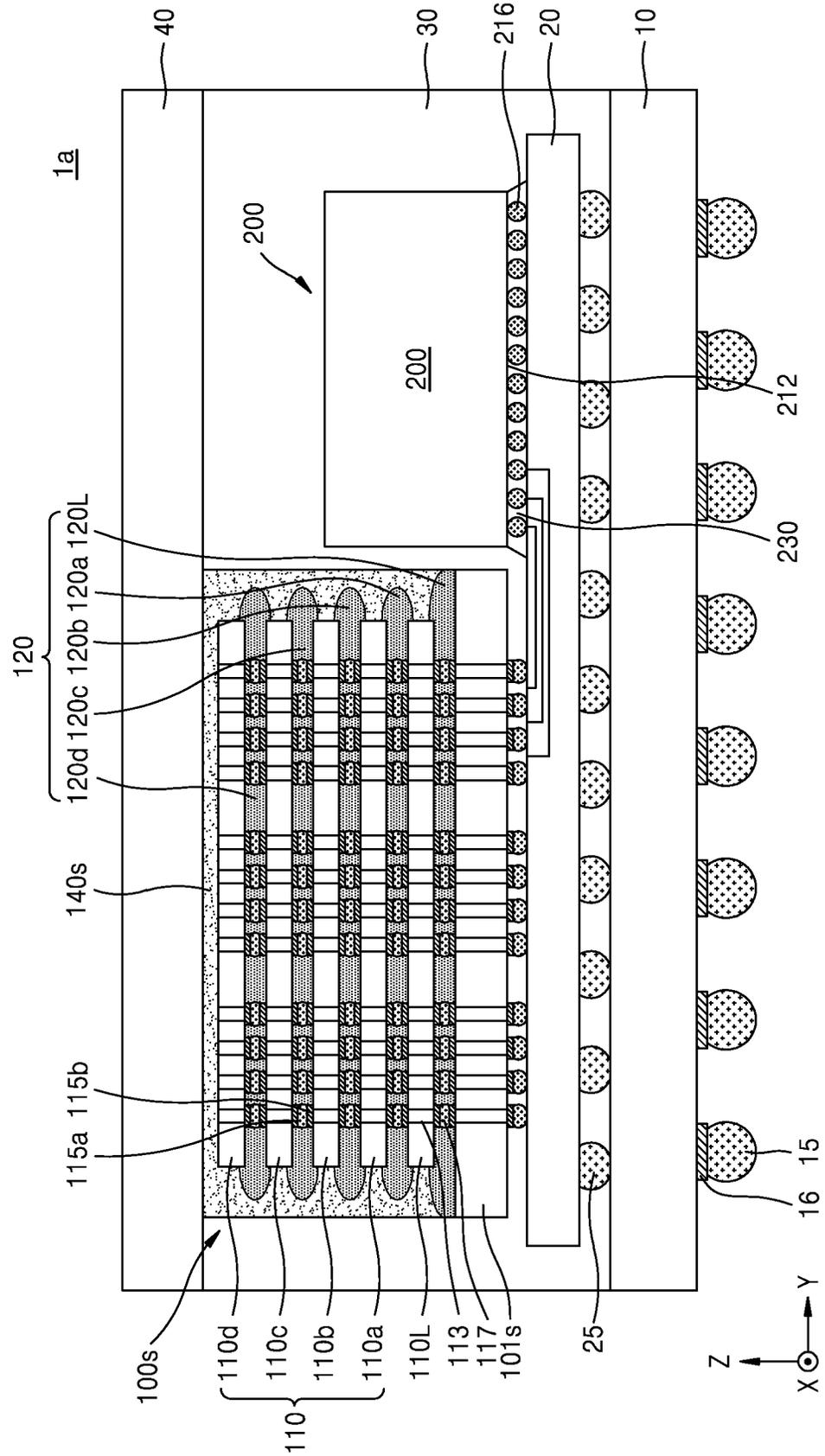


FIG. 10



1

SEMICONDUCTOR PACKAGE AND METHOD OF MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This U.S. non-provisional patent application claims the benefit of priority under 35 U.S.C. § 119 to Korean Patent Application No. 10-2020-0001579, filed on Jan. 6, 2020, in the Korean Intellectual Property Office, the disclosure of which is incorporated by reference in its entirety herein.

BACKGROUND

1. Technical Field

The inventive concept relates to a semiconductor package and a method of manufacturing the same, and more particularly, to a semiconductor package that is resistant to warpage and capable of preventing poor terminal contact and a method of manufacturing the same.

2. Discussion of Related Art

A non-conductive film (NCF) is frequently used as an underfill in a semiconductor package. A semiconductor package may be a metal, plastic, glass, or ceramic casing containing one or more discrete semiconductor devices or integrated circuits. However, as a size and thickness of the semiconductor devices are reduced, a terminal of one of the semiconductor devices may fail to properly contact a terminal of another one of the semiconductor devices or a warpage of one or more of the semiconductor devices may occur.

SUMMARY

At least one embodiment of the inventive concept relates to a semiconductor package including a semiconductor device having a terminal that is less likely to make poor contact with another terminal and that resists warpage.

At least one embodiment, of the inventive concept relates to a method of manufacturing a semiconductor package including a semiconductor device having a terminal that is less likely to make poor contact with another terminal and that resists warpage.

According to an exemplary embodiment of the inventive concept, there is provided a semiconductor package including a substrate, a plurality of semiconductor devices stacked on the substrate, a plurality of underfill fillets (e.g., non-conductive films) disposed between the plurality of semiconductor devices and between the substrate and the plurality of semiconductor devices, and a molding resin surrounding the plurality of semiconductor devices. At least one of the underfill fillets is exposed from side surfaces of the molding resin.

According to an exemplary embodiment of the inventive concept, there is provided a semiconductor package including a package substrate, an interposer substrate stacked on the package substrate, a first sub-package and a second sub-package laterally arranged on the interposer substrate, and a first molding resin surrounding side surfaces of the first sub-package and the second sub-package. The first sub-package includes a first sub-package substrate, a plurality of memory devices stacked on the first sub-package substrate, and a plurality of underfill fillets disposed between the plurality of memory devices and between the first

2

sub-package substrate and the plurality of memory devices. At least one of the underfill fillets horizontally protrudes from side surfaces of the plurality of memory devices by about 200 μm to about 500 μm .

According to an exemplary embodiment of the inventive concept, there is provided a semiconductor package including a package substrate, a plurality of semiconductor devices stacked on the package substrate, a plurality of underfill fillets disposed between the plurality of semiconductor devices and between the package substrate and the plurality of semiconductor devices, and a molding resin surrounding the plurality of semiconductor devices. Each of the underfill fillets protrudes to an outside of side surfaces of the plurality of semiconductor devices. At least one of the underfill fillets is exposed from side surfaces of the molding resin and side surfaces of the underfill fillet exposed from the side surfaces of the molding resin among the underfill fillets are coplanar with the side surfaces of the molding resin. A distance between side surfaces of the plurality of semiconductor devices and side surfaces of the molding resin is no more than 500 μm .

According to an exemplary embodiment the inventive concept, there is provided a method of manufacturing a semiconductor package, including mounting a first non-conductive film (NCF) and a first semiconductor chip on a package substrate under a first mounting condition and mounting a second NCF and a second semiconductor chip on the first semiconductor chip under a second mounting condition. The first mounting condition and the second mounting condition are a temperature, pressure, and pressing time determined to minimize warpage of the semiconductor package. For example, one of the mounting conditions could be designed to fluidize one of the NCFs so that it is wider than the other NCF. For example, one of the mounting conditions could be designed to fluidize one of the NCFs so it becomes exposed from side surfaces of a molding resin surrounding the semiconductor chips and the other NCF remains within the molding resin.

According to an exemplary embodiment of the inventive concept, there is provided a method of manufacturing a semiconductor package, including arranging and mounting a plurality of first non-conductive films (NCF) and a plurality of first semiconductor devices corresponding to the plurality of first NCFs on a substrate under a first mounting condition, mounting a plurality of second NCFs and a plurality of second semiconductor devices on corresponding ones of the plurality of first semiconductor devices under a second mounting condition, forming a molding resin surrounding side surfaces of the plurality of first semiconductor devices and the plurality of second semiconductor devices, and performing singulation to obtain an individual semiconductor package. At least one of NCFs among the first NCFs and the second NCFs contact each other after neighboring NCFs are mounted.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the inventive concept will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1A is a side cross-sectional view of a semiconductor package according to an exemplary embodiment of the inventive concept and FIG. 1B is a side view of the semiconductor package of FIG. 1A observable from a side;

FIG. 2 is a partial side cross-sectional view illustrating two adjacent underfill fillets according to an exemplary embodiment of the inventive concept;

FIG. 3A is a side cross-sectional view of a semiconductor package according to an exemplary embodiment of the inventive concept and FIG. 3B is a side view of a semiconductor package observable from a side;

FIG. 4 is a flowchart illustrating a method of manufacturing a semiconductor package according to an exemplary embodiment of the inventive concept;

FIGS. 5A to 5G are side cross-sectional views illustrating a method of manufacturing the semiconductor package according to an exemplary embodiment of the inventive concept;

FIG. 6 is a side cross-sectional view illustrating a relationship between adjacent semiconductor devices and underfill fillets when a first non-conductive film (NCF) is changed into a first underfill fillet;

FIGS. 7A to 7D are partial plan views illustrating processes in which first NCFs are gradually fluidized in lower portions of a plurality of adjacent first semiconductor devices and contact each other;

FIG. 8 is a schematic view illustrating adjustment of a warpage characteristic of a semiconductor package;

FIG. 9 is a side cross-sectional view illustrating a semiconductor package according to an exemplary embodiment of the inventive concept; and

FIG. 10 is a side cross-sectional view illustrating a semiconductor package according to an exemplary embodiment of the inventive concept.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Hereinafter, exemplary embodiments of the inventive concept will be described in detail with reference to the accompanying drawings. Like reference numerals refer to like elements throughout and previously given description will be omitted.

That a semiconductor package is in the form of “cry” represents a type of warpage in which the center of the semiconductor package is raised compared to the edges and that a semiconductor package is in the form of “smile” represents a type of warpage in which the edges of the semiconductor package rise compared to the center.

FIG. 1A is a side cross-sectional view of a semiconductor package 100 according to an exemplary embodiment of the inventive concept. FIG. 1B is a side view of the semiconductor package 100 observable from the side.

Referring to FIGS. 1A and 1B, the semiconductor package 100 includes a plurality of semiconductor devices 110 stacked on a substrate 101.

In some embodiments, the substrate 101 may be a printed circuit board (PCB). In this case, the substrate 101 may include a base substrate and upper pads 106b and lower pads 106a respectively formed on an upper surface and a lower surface of the base substrate. The upper pads 106b and lower pads 106a may be exposed by a solder resist layer (not shown) covering the upper surface and lower surface of the base substrate. For example, a solder resist layer may be formed over the lower pads 106a and portions of the solder resist layer may be removed to expose upper surfaces of the lower pads 106a.

The base substrate may include at least one material selected from phenol resin, epoxy resin, and polyimide. For example, the base substrate may include at least one material selected from FR4, tetrafunctional epoxy, polyphenylene

ether, epoxy/polyphenylene oxide, BT (bismaleimide triazine), Thermount, cyanate ester, polyimide, and liquid crystal polymer.

The upper pads 106b and lower pads 106a may include copper (Cu), aluminum (Al), nickel (Ni), stainless steel, or beryllium copper (BeCu). An internal wiring line (not shown) electrically connecting the upper pads 106b to the lower pads 106a may be formed in the base substrate. The upper pads 106b and lower pads 106a may be portions exposed by the solder resist layer of a circuit wiring line obtained by forming a Cu foil on the upper surface and the lower surface of the base substrate and patterning the Cu foil.

In some embodiments, the substrate 101 may be an interposer (e.g., an interposer substrate). In this case, the substrate 101 may include the base substrate formed of a semiconductor material and the upper pads 106b and the lower pads 106a respectively formed on the upper surface and the lower surface of the base substrate. The base substrate may be formed of, for example, a silicon wafer. In addition, the internal wiring line (not shown) may be formed in the upper surface, the lower surface, or the inside of the base substrate. In addition, through vias 103 electrically connecting the upper pads 106b to the lower pads 106a may be formed in the base substrate.

External connection terminals 105 may be attached onto the lower surface of the substrate 101. The external connection terminals 105 may be attached onto, for example, the lower pads 106a. The external connection terminals 105 may be, for example, solder balls or bumps. The external connection terminals 105 may electrically connect the semiconductor package 100 to an external device. For example, the external connection terminals 105 may be made of a conductive material.

The plurality of semiconductor devices 110 may be mounted on the substrate 101. The plurality of semiconductor devices 110 may include a first semiconductor device 110a, a second semiconductor device 110b, a third semiconductor device 110c, and a fourth semiconductor device 110d that are sequentially stacked on the substrate 101.

The first to fourth semiconductor devices 110a, 110b, 110c, and 110d may have various semiconductor elements on an active surface of a semiconductor substrate. In some embodiments, the semiconductor substrate of the first to fourth semiconductor devices 110a, 110b, 110c, and 110d may include silicon (Si). In other embodiments, the semiconductor substrate of the first to fourth semiconductor devices 110a, 110b, 110c, and 110d may include a semiconductor atom such as germanium (Ge) or a compound semiconductor such as silicon carbide (SiC), gallium arsenide (GaAs), indium arsenide (InAs), or indium phosphide (InP). In some embodiments, the semiconductor substrate of the first to fourth semiconductor devices 110a, 110b, 110c, and 110d may have a silicon-on-insulator (SOI) structure. For example, the semiconductor substrate may include a buried oxide (BOX) layer. In some embodiments, the semiconductor substrate of the first to fourth semiconductor devices 110a, 110b, 110c, and 110d may include a conductive region, for example, a well doped with impurities. In some embodiments, the semiconductor substrate of the first to fourth semiconductor devices 110a, 110b, 110c, and 110d may have various device isolation structures such as a shallow trench isolation (STI) structure.

In the first to fourth semiconductor devices 110a, 110b, 110c, and 110d, semiconductor devices including a plurality of various kinds of individual devices may be formed. The plurality of various kinds of individual devices may include

various microelectronic devices, for example, a metal-oxide-semiconductor field effect transistor (MOSFET) such as a complementary metal-insulator-semiconductor (CMOS) transistor, a large scale integration (LSI) circuit such as an image sensor. For example, the image sensor may be a CMOS image sensor (CIS), a micro-electro-mechanical system (MEMS), an active device, or a passive device.

In some embodiments, the plurality of individual devices may be electrically connected to the conductive region of the semiconductor substrate of the first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d**. The semiconductor device may further include a conductive wiring line or a conductive plug electrically connecting at least two of the plurality of individual devices or the plurality of individual devices to the conductive region of the semiconductor substrate of the first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d**. In addition, each of the plurality of individual devices may be electrically isolated by an insulating layer from each of other adjacent individual devices.

Each of the first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d** may be, for example, a memory semiconductor chip. The memory semiconductor chip may be, for example, a volatile memory semiconductor chip such as dynamic random access memory (DRAM) or static random access memory (SRAM) or a non-volatile memory semiconductor chip such as phase-change random access memory (PRAM), magnetoresistive random access memory (MRAM), ferroelectric random access memory (FeRAM), or resistive random access memory (RRAM).

At least one of the plurality of semiconductor devices **110** may be a logic semiconductor chip and the remaining ones may be memory semiconductor chips. For example, the lowermost first semiconductor device **110a** of the plurality of semiconductor devices **110** may be the logic semiconductor chip and the remaining second to fourth semiconductor devices **110b**, **110c**, and **110d** may be the memory semiconductor chips. For example, the lowermost first semiconductor device **110a** of the plurality of semiconductor devices **110** may be a controller chip (e.g., including a memory controller) for controlling the remaining second to fourth semiconductor devices **110b**, **110c**, and **110d** and the remaining second to fourth semiconductor devices **110b**, **110c**, and **110d** may be high bandwidth memory (HBM) DRAM semiconductor chips.

In FIGS. 1A and 1B, it is illustrated that four semiconductor devices are stacked on the substrate **101**. However, embodiments of the inventive concept are not limited thereto as the number of semiconductor devices stacked on the substrate **101** may be 2, 3, 5, or more. When all of the plurality of semiconductor devices **110** are memory semiconductor devices, the number of semiconductor devices **110** may be a multiple of 2. When the plurality of semiconductor devices **110** include one or more logic semiconductor devices and the remaining semiconductor devices are memory semiconductor devices, the number of memory semiconductor devices included in the plurality of semiconductor devices **110** may be a multiple of 2. In some embodiments, the memory semiconductor devices included in the plurality of semiconductor devices **110** may be the same kind of memory semiconductor devices.

The first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d** included in the plurality of semiconductor devices **110** may include a plurality of through electrodes **113**. The plurality of through electrodes **113** may be arranged in a matrix, for example, with a pitch of tens of μm . Each of the plurality of through electrodes **113** may have a diameter of, for example, several μm to several tens of μm .

In some embodiments, each of the plurality of through electrodes **113** may have a diameter of about 5 μm to about 15 μm and may be arranged with a pitch of about 25 μm to about 50 μm . For example, the electrodes **113** in a given one of the semiconductor devices **110** stacked in a Z direction may be spaced 30 μm apart from one another in a Y direction.

The first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d** included in the plurality of semiconductor devices **110** may be electrically connected to each other by the plurality of corresponding through electrodes **113**. The first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d** included in the plurality of semiconductor devices **110** may be electrically connected to the substrate **101** by the plurality of through electrodes **113**. The plurality of through electrodes **113** may provide at least one of a signal, power source, or ground for the plurality of semiconductor devices **110**.

Connection terminals **117** connected to the plurality of through electrodes **113** may be attached to lower surfaces of the first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d** included in the plurality of semiconductor devices **110**. Each of the connection terminals **117** may have a diameter of, for example, tens of μm . In an exemplary embodiment of the inventive concept, the diameter of each of the connection terminals **117** is greater than the diameter of each of the plurality of through electrodes **113** and less than the pitch with which the plurality of through electrodes **113** are arranged. For example, each of the connection terminals **117** may have a diameter of about 20 μm .

Each of the plurality of through electrodes **113** may be formed of through silicon via (TSV). Each of the plurality of through electrodes **113** may include a wiring metal layer and a barrier metal layer surrounding the wiring metal layer.

The wiring metal layer may include Cu or tungsten (W). For example, the wiring metal layer may be formed of Cu, CuSn, CuMg, CuNi, CuZn, CuPd, CuAu, CuRe, CuW, W, or a W alloy. However, the inventive concept is not limited thereto. For example, the wiring metal layer may include one or more of Al, Au, Be, Bi, Co, Cu, Hf, In, Mn, Mo, Ni, Pb, Pd, Pt, Rh, Re, Ru, Ta, Te, Ti, W, Zn, and Zr and a stack structure of two or more of Al, Au, Be, Bi, Co, Cu, Hf, In, Mn, Mo, Ni, Pb, Pd, Pt, Rh, Re, Ru, Ta, Te, Ti, W, Zn, and Zr.

The barrier metal layer may include at least one material selected from W, WN, WC, Ti, TiN, Ta, TaN, Ru, Co, Mn, WN, Ni, and NiB and may be formed of a single layer or a multilayer.

However, a material of each of the plurality of through electrodes **113** is not limited thereto. The barrier metal layer and the wiring metal layer may be formed by a physical vapor deposition (PVD) process or a chemical vapor deposition (CVD) process. However, the inventive concept is not limited thereto. In some embodiments, a spacer insulating layer may be interposed between the plurality of through electrodes **113** and the semiconductor substrate including the plurality of semiconductor devices **110**. The spacer insulating layer may prevent the semiconductor devices formed in the first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d** included in the plurality of semiconductor devices **110** from directly contacting the plurality of through electrodes **113**. The spacer insulating layer may be formed of an oxide layer, a nitride layer, a carbide layer, polymer, or a combination of the above materials. In some embodiments, the CVD process may be used to form the spacer insulating layer. The spacer insulating layer may be formed of an ozone/tetra-ethyl ortho-silicate (O_3/TEOS) based high

aspect ratio process (HARP) oxide layer formed by a sub-atmospheric CVD process.

In an exemplary embodiment of the inventive concept, the plurality of through electrodes **113** directly connect active surfaces and non-active surfaces of the first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d** included in the plurality of semiconductor devices **110** to each other. However, the inventive concept is not limited thereto. The plurality of through electrodes **113** may be formed in any one of a via-first structure, a via-middle structure, and a via-last structure. Since a method of manufacturing the via-first structure, the via-middle structure, or the via-last structure is disclosed in a plurality of documents such as Three Dimensional System Integration published by Springer in 2011, 3D Integration for VLSI Systems published by CRC Press in 2012, and Designing TSVs for 3D Integrated Circuits published by Springer in 2013, detailed description thereof is omitted.

The lower pads **115a** and the upper pads **115b** electrically connected to the through electrodes **113** may be provided on the lower surfaces and upper surfaces of the first to fourth semiconductor devices **110a**, **110b**, **110c**, **110d** included in the plurality of semiconductor devices **110**. The lower pads **115a** and the upper pads **115b** may be formed in positions corresponding to the through electrodes **113** and may be electrically connected to the plurality of through electrodes **113**. However, the inventive concept is not limited thereto. For example, the lower pads **115a** and the upper pads **115b** may be formed in positions apart from the through electrodes **113** and may be electrically connected to the through electrodes **113** via a redistribution layer. The lower pads **115a** and the upper pads **115b** may be defined by standard protocol such as JEDEC standards and each of the lower pads **115a** and the upper pads **115b** may have a thickness of hundreds of nm to several μm . In addition, the lower pads **115a** and the upper pads **115b** may include at least one of Al, Cu, Ta, Ti, W, Ni, and Au.

A first molding resin **140** surrounding side surfaces of the plurality of semiconductor devices **110** may be provided on the substrate **101**. The first molding resin **140** may be formed of, for example, an epoxy molding compound (EMC). In some embodiments, the first molding resin **140** may be provided to cover an upper surface of the uppermost semiconductor device (here, the fourth semiconductor device **110d**) among the plurality of semiconductor devices **110**. In other embodiments, the first molding resin **140** may expose the upper surface of the uppermost semiconductor device (here, the fourth semiconductor device **110d**) among the plurality of semiconductor devices **110**. For example, a portion of the first molding resin **140** may be removed to expose the upper surface of the fourth semiconductor device **110d**.

An underfill fillet **120** (e.g., an underfill layer) may be provided among the plurality of semiconductor devices **110** and between the substrate **101** and the plurality of semiconductor devices **110**. For example, an underfill layer may be located between the substrate **101** and a bottom one of the semiconductor devices **110**, and an underfill layer may be located between each pair of the semiconductor devices **110**.

The underfill fillet **120** may fill spaces between the first semiconductor device **110a** and the substrate **101**. In addition, the underfill fillet **120** may fill spaces between the second to fourth semiconductor devices **110b**, **110c**, and **110d**. The underfill fillet **120** may increase adhesive strength of components and/or prevent a decrease in physical strength due to deformation of the components. In some embodiments, the underfill fillet **120** is provided in the

spaces to remove an empty space into which foreign material or moisture may permeate and/or to prevent electrical migration.

The underfill fillet **120** may protrude to the outsides of the side surfaces of the first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d** while filling spaces between the package substrate **101** and the first to fourth semiconductor devices **110a**, **110b**, **110c**, and **110d**. In an exemplary embodiment of the inventive concept, a first underfill fillet **120a** is disposed in a space between the substrate **101** and the first semiconductor device **110a** and protrudes to the outside from side surfaces of the first semiconductor device **110a**. In an exemplary embodiment of the inventive concept, a second underfill fillet **120b** is disposed in a space between the first semiconductor device **110a** and the second semiconductor device **110b** and protrude to the outside from side surfaces of the second semiconductor device **110b**. In an exemplary embodiment of the inventive concept, a third underfill fillet **120c** is disposed in a space between the second semiconductor device **110b** and the third semiconductor device **110c** and protrudes to the outside from side surfaces of the third semiconductor device **110c**. In an exemplary embodiment of the inventive concept, a fourth underfill fillet **120d** is disposed in a space between the third semiconductor device **110c** and the fourth semiconductor device **110d** and protrudes to the outside from side surfaces of the fourth semiconductor device **110d**.

In some embodiments, the first to fourth underfill fillets **120a** to **120d** do not contact each other and are separated from each other. In some embodiments, two adjacent underfill fillets of the first to fourth underfill fillets **120a** to **120d** may contact each other with an interface interposed therebetween. For example, an upper surface of the interface may contact one of two adjacent underfill fillets and a lower surface of the interface may contact the other of the two adjacent underfill fillets.

FIG. 2 is a partial side cross-sectional view illustrating that two adjacent underfill fillets according to an exemplary embodiment of the inventive concept.

Referring to FIG. 2, two adjacent underfill fillets **120j** and **120k** among three semiconductor devices **110i**, **110j**, and **110k** are provided. The two underfill fillets **120j** and **120k** protrude to the outside from side surfaces of the semiconductor devices **110i**, **110j**, and **110k**. The two underfill fillets **120j** and **120k** swell up and down as well as in a lateral direction when protruding to the outside from the side surfaces of the semiconductor devices **110i**, **110j**, and **110k**.

In detail, the j-th underfill fillet **120j** and the j-th semiconductor device **110j** are arranged on the i-th semiconductor device **110i** and the j-th underfill fillet **120j** is heated and pressed so that the j-th underfill fillet **120j** protrudes to the outside from the side surface of the j-th semiconductor device **110j** and is cured. For example, physical pressure may be applied to the j-th underfill fillet **120j** to cause the j-th underfill fillet **120j** to be pressed.

Then, the k-th underfill fillet **120k** and the k-th semiconductor device **110k** are arranged on the j-th semiconductor device **110j** and the k-th underfill fillet **120k** is heated and pressed so that the k-th underfill fillet **120k** protrudes to the outside from the side surface of the k-th semiconductor device **110k**. Since the k-th underfill fillet **120k** is heated and pressed, the k-th underfill fillet **120k** swells up and down while protruding to the side surface of the k-th semiconductor device **110k**. When swelling occurs more than a certain level, the k-th underfill fillet **120k** contacts the j-th underfill fillet **120j** that is previously formed. At this time, since the

j-th underfill fillet **120j** is previously cured, an interface IF may be formed between the j-th underfill fillet **120j** and the k-th underfill fillet **120k**.

In addition, the k-th underfill fillet **120k** does not contact with the j-th underfill fillet **120j** while j-th underfill fillet **120j** has fluidity. Instead, after the j-th underfill fillet **120j** is cured, the k-th underfill fillet **120k** is reflowed and contacts the cured j-th underfill fillet **120j**. Therefore, at a contact point, a surface of the j-th underfill fillet **120j** and a surface of the k-th underfill fillet **120k** may contact each other at a predetermined angle θ . The angle θ is formed by tangential lines at the contact point, which may be an acute angle, a right angle, or an obtuse angle. However, the inventive concept is not limited thereto.

Referring back to FIGS. 1A and 1B, the underfill fillet **120** may be, for example, bisphenol A (BPA) epoxy resin, bisphenol F (BPF) epoxy resin, aliphatic epoxy resin, or cycloaliphatic epoxy resin and may further include powder such as silica, alumina, zirconia, titania (e.g., titanium dioxide), ceria, magnesia, silicon carbide, or aluminum nitride as an inorganic filler.

In some embodiments, the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** included in the underfill fillet **120** may be the same kind of underfill fillets. In other embodiments, at least two of the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** may have different contents and kinds of inorganic fillers, different kinds of resin, and/or resin with different physical properties.

At least one of the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** may protrude more to the outside than the other underfill fillet(s). As illustrated in FIG. 1A, the first underfill fillet **120a** may protrude to the outside by **L1** and the second to fourth underfill fillets **120b**, **120c**, and **120d** may protrude to the outside by **L2**. In an exemplary embodiment, **L1** is greater than **L2**. In some embodiments, **L1** may be no more than about 500 μm . In some embodiments, **L1** may be about 30 μm to about 450 μm , about 60 μm to about 400 μm , about 100 μm to about 350 μm , or about 120 μm to about 300 μm .

When **L1** is too large, an area occupied by the semiconductor package **100** may be excessively large. When **L1** is too small, tolerance is so small that it may be difficult to manufacture the semiconductor package **100**.

The underfill fillets protruding more to the outside than the other underfill fillet(s) among the underfill fillets **120** may be exposed to the outside from side surfaces of the molding resin **140**. As illustrated in FIG. 1A, the first underfill fillet **120a** may protrude more to the outside than the other underfill fillets and extend up to the side surfaces of the molding resin **140**. In FIG. 1A, it is illustrated that the first underfill fillet **120a** protrudes most to the outside. However, those skilled in the art may understand that another underfill fillet **120** may protrude most to the outside to be exposed to the side surfaces of the molding resin **140**.

In some embodiments, at least one of the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** is not exposed from the side surfaces of the molding resin **140**. In some embodiments, at least two of the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** may be exposed from the side surfaces of the molding resin **140**. In some embodiments, the first underfill fillet **120a** may be exposed from the side surfaces of the molding resin **140** and at least one of the second to fourth underfill fillets **120b**, **120c**, and **120d** may be exposed from the side surfaces of the molding resin **140**.

In an exemplary embodiment of the inventive concept, the underfill fillet extending to the side surfaces of the molding resin **140** and exposed from the side surfaces of the molding

resin **140** (here, the first underfill fillet **120a**) directly contacts the substrate **101**. As illustrated in FIG. 1B, the exposed first underfill fillet **120a** may contact the substrate **101** at the side surfaces of the molding resin **140** along a length **C**.

In other embodiments, the exposed underfill fillet does not contact the substrate **101** at the side surfaces of the molding resin **140**.

The substrate **101** and the first semiconductor device **110a** may be spaced apart from each other by a first distance **ha**. The first semiconductor device **110a** and the second semiconductor device **110b** may be apart from each other by a second distance **hb**. The second semiconductor device **110b** and the third semiconductor device **110c** may be apart from each other by a third distance **hc**. The third semiconductor device **110c** and the fourth semiconductor device **110d** may be apart from each other by a fourth distance **hd**.

In an exemplary embodiment, the first to fourth distances **ha** to **hd** differ from one another. In an exemplary embodiment, an underfill fillet protruding more from the side surfaces of the plurality of semiconductor devices **110** to the outside has a smaller distance than another one of the semiconductor devices **110** that protrudes less from the sides surface. In some embodiments, as illustrated in FIG. 1A, the first underfill fillet **120a** horizontally protrudes more than the other underfill fillets and the first distance **ha** is less than the other distances (the second distance **hb**, the third distance **hc**, and the fourth distance **hd**).

As described above, at least two of the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** may have different contents and kinds of inorganic fillers, different kinds of resin, and/or resin with different physical properties.

In accordance with contents and kinds of inorganic fillers and kinds and physical properties of resin, the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** may have, for example, different coefficients of thermal expansion (CTE), viscosities, and glass transition temperatures (T_g).

In some embodiments, by controlling the CTEs of the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d**, warpage of the semiconductor package **100** may be controlled. Warpage of the semiconductor package **100** may be controlled by controlling degrees to which the underfill fillets **120** (here, the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d**) horizontally extend. That is, at least two of the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** may have different physical properties and lengths with which the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** horizontally extend and protrude may be different from each other. In this case, a physical property of an underfill fillet horizontally extending and protruding with a greater length affects the warpage of the semiconductor package **100** more than a physical property of an underfill fillet horizontally extending and protruding with a less length.

In the embodiment illustrated in FIG. 1A, since a length with which the first underfill fillet **120a** horizontally extends is greater than lengths with which the second to fourth underfill fillets **120b**, **120c**, and **120d** horizontally extend, the first underfill fillet **120a** affects the warpage of the semiconductor package **100** more than the second to fourth underfill fillets **120b**, **120c**, and **120d**.

For example, when the length with which the first underfill fillet **120a** protrudes is the same as the length with which the second underfill fillet **120b** protrudes as **L2**, the semiconductor package **100** may be bent in the form of a smile. At this time, it is assumed that the first underfill fillet **120a** has a CTE greater than that of the second underfill fillet

120b. In such a case, by simply having the first underfill fillet **120a** horizontally protrude with a length greater than L_2 , horizontal contraction of the first underfill fillet **120a** may be reflected more. As a result, a degree to which the semiconductor package **100** is bent in the form of smile may be reduced or warpage may be prevented. That is, a degree of the warpage of the semiconductor package **100** may be controlled by increasing the length with which the first underfill fillet **120a** horizontally extends without another change. This is because an effect of the first underfill fillet **120a** with the greater CTE increases.

In FIG. 1A, it is illustrated that the degree to which the first underfill fillet **120a** protrudes is greatest. However, another underfill fillet, for example, the second underfill fillet **120b**, the third underfill fillet **120c**, or the fourth underfill fillet **120d** may horizontally protrude most. As described above, by increasing the degree to which the second underfill fillet **120b**, the third underfill fillet **120c**, or the fourth underfill fillet **120d** horizontally protrudes, the physical property of a certain underfill fillet may be rendered to contribute more to the warpage of the semiconductor package **100**.

In addition, in manufacturing the semiconductor package **100**, when the underfill fillet **120** is reflowed (e.g., fluidized) by applying heat and pressure, a portion of the underfill fillet **120** positioned around the center of the semiconductor devices **110** is fluidized toward the outside. At this time, the portion of the underfill fillet **120** fluidized to the outside may be concentrated at external edges of the semiconductor devices **110** so that a normal connection of the semiconductor devices **110** may deteriorate. In an exemplary embodiment, the underfill fillet **120** around the centers of the semiconductor devices **110** and between the centers and the edges of the semiconductor devices **110** is simultaneously reflowed and concentrated around the edges of the semiconductor devices **110**. The concentrated underfill fillet **120** may lift the edges of the semiconductor devices **110** up. Therefore, connection of the semiconductor devices **110** may deteriorate. In particular, as a thickness of each of the semiconductor devices **110** becomes smaller, the semiconductor devices **110** are affected more by this lifting.

Furthermore, the second to fourth underfill fillets **120b**, **120c**, and **120d** may horizontally protrude more easily than the first underfill fillet **120a** positioned under the lowermost semiconductor device (in FIG. 1A, the first semiconductor device **110a**). That is, the second to fourth underfill fillets **120b**, **120c**, and **120d** may horizontally move and move up and down while being fluidized out of spaces among the semiconductor devices **110**. On the other hand, the first underfill fillet **120a** may move only horizontally or upward while being fluidized out of a space between the first semiconductor device **110a** and the substrate **101**. Therefore, fluidization of the first underfill fillet **120a** may be limited in comparison with the second to fourth underfill fillets **120b**, **120c**, and **120d** so that the first underfill fillet **120a** may protrude more in a horizontal direction.

By having the first underfill fillet **120a** horizontally protrude enough, a lifting problem of the semiconductor devices **110** may be solved and limitations on a fluidizing path of the first underfill fillet **120a** may be relieved.

In some embodiments, at least two of the underfill fillets **120** horizontally protrude more than the other underfill fillet(s). In some embodiments, at least two of the underfill fillets **120** are exposed from side surfaces of the molding resin **140** to the outside. FIG. 3A is a side cross-sectional view of a semiconductor package **100a** according to an

exemplary embodiment of the inventive concept and FIG. 3B is a side view of the semiconductor package **100a** observable from a side.

Referring to FIGS. 3A and 3B, the semiconductor package **100a** is the same as the semiconductor package **100** described with reference to FIGS. 1A and 1B except that an underfill fillet other than the first underfill fillet **120a**, that is, a third underfill fillet **120c'** extends to the side surfaces of the molding resin **140** and is exposed from the side surfaces of the molding resin **140**. Therefore, hereinafter, such a difference will be mainly described and a previously given description may be omitted.

The third underfill fillet **120c'** horizontally extends more than the third underfill fillet **120c** of FIG. 1A. In FIG. 3A, it is illustrated that the first to fourth underfill fillets **120a**, **120b**, **120c'**, and **120d** do not contact each other. However, two of the first to fourth underfill fillets **120a**, **120b**, **120c'**, and **120d** may contact each other as illustrated in FIG. 2. When the third underfill fillet **120c'** of FIG. 3A is obtained by having the third underfill fillet **120c** of FIG. 1 horizontally protrude more, a third distance hc' between the second semiconductor device **110b** and the third semiconductor device **110c** may be smaller than the third distance hc of FIG. 1A.

As described above with reference to FIGS. 1A and 1B, in order to precisely control the warpage of the semiconductor package **100a**, lengths with which the second to fourth underfill fillets **120b**, **120c'**, and **120d** horizontally extend may also be controlled.

For example, like in the semiconductor package **100** of FIG. 1A, the warpage of the semiconductor package **100a** may be controlled by controlling the length with which the first underfill fillet **120a** protrudes. Nevertheless, the warpage of the semiconductor package **100a** of FIG. 3A may not be sufficiently controlled. At this time, by controlling the length with which the third underfill fillet **120c'** protrudes, the warpage of the semiconductor package **100a** may be more precisely controlled.

As described above with reference to FIG. 1A, even though the length with which the first underfill fillet **120a** protrudes has been increased, the semiconductor package **100a** may be bent in the form of a smile. At this time, it is assumed that the third underfill fillet **120c'** has a CTE smaller than that of the second underfill fillet **120b** and the second underfill fillet **120b** has a CTE smaller than that of the first underfill fillet **120a**. In this case, by simply having the third underfill fillet **120c'** horizontally protrude with a length greater than L_2 , a characteristic in which the third underfill fillet **120c'** horizontally contracts may be reflected more to the semiconductor package **100a**. That is, the CTE of the third underfill fillet **120c'** is less than the CTE of the first underfill fillet **120a** and the characteristic of the third underfill fillet **120c'** horizontally contracting less than the first underfill fillet **120a** is reflected more to the semiconductor package **100a**. As a result, a degree to which the semiconductor package **100a** is bent in the form of a smile may be reduced.

In the semiconductor package according to at least one exemplary embodiment of the inventive concept, it is possible to prevent poor contact of a terminal and to minimize the warpage of the semiconductor package.

FIG. 4 is a flowchart illustrating a method of manufacturing a semiconductor package according to an exemplary embodiment of the inventive concept. FIGS. 5A to 5G are side cross-sectional views illustrating a method of manufacturing the semiconductor package according to an exemplary embodiment of the inventive concept.

Referring to FIGS. 4 and 5A, a plurality of first semiconductor devices **110a** are arranged on a substrate **101** and are mounted on the substrate **101** under a first mounting condition in operation **S110**.

In FIG. 5A, only one first semiconductor device **110a** is illustrated. However, on the substrate **101** extending in X and Y directions, the plurality of semiconductor devices **110a** may be arranged and mounted, for example, in a grid configuration.

First non-conductive films (NCF) **120a'** may be respectively attached to a corresponding one of the plurality of first semiconductor devices **110a**. In an exemplary embodiment, a dimension of the first NCF **120a'** in a horizontal direction (a direction of an XY plane) is the same as that of the first semiconductor device **110a**. In an exemplary embodiment, a thickness $h_{a'}$ of the first NCF **120a'** is greater than a height of each of the connection terminals **117** in a Z direction. In this case, the connection terminals **117** may be surrounded by the first NCF **120a'**. However, in other embodiments, lower ends of the connection terminals **117** may be partially exposed from the first NCF **120a'**.

Since the substrate **101** and the first semiconductor device **110a** are described in detail with reference to FIG. 1A, a detailed description thereof will be omitted.

Referring to FIG. 5B, the first semiconductor device **110a** is mounted on the substrate **101** under the first mounting condition. The first mounting condition includes a temperature, pressure, and time during which the first semiconductor device **110a** is mounted.

In some embodiments, the temperature of the first mounting condition may be about 180° C. to about 280° C. In some embodiments, the pressure of the first mounting condition may be about 5 kPa to about 200 kPa. The time of the first mounting condition may be about 1 second to about 100 seconds. The temperature, pressure, and time are closely correlated and, for example, by increasing a time a little while reducing a pressure a little under a certain mounting condition, the same mounting result may be obtained. In addition, for example, by increasing a temperature a little while reducing a time a little under a certain mounting condition, the same mounting result may be obtained. In addition, for example, by increasing a pressure a little while reducing a temperature a little under a certain mounting condition, the same mounting result may be obtained. A degree to which the first NCF **120a'** is fluidized and horizontally protrudes may be controlled by properly controlling the mounting condition such as the temperature, pressure, and time.

By cooling the first NCF **120a'** that is fluidized and protrudes, the first underfill fillet **120a** may be obtained.

By using the method of manufacturing the semiconductor package according to at least one exemplary embodiment of the inventive concept, it is possible to prevent contact failure of a terminal and to minimize the warpage of the semiconductor package.

FIG. 6 is a side cross-sectional view illustrating a relationship between adjacent semiconductor devices and underfill fillets when the first NCF **120a'** is changed into the first underfill fillet **120a**.

Referring to FIG. 6, the first underfill fillets **120a** are respectively provided to the adjacent two first semiconductor devices **110a**. In some embodiments, the adjacent first underfill fillets **120a** contact each other and are partially integrated. Then, the first semiconductor devices **110a** and the first underfill fillets **120a** may be molded by a molding resin. When the first semiconductor devices **110a** and the first underfill fillets **120a** are molded by the molding resin

and then, are separated and singulated along a separation line **120aSL**, side surfaces of the first underfill fillets **120a** may be exposed from side surfaces of the molding resin.

FIGS. 7A to 7D are partial plan views illustrating processes in which first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4** are gradually fluidized in lower portions of a plurality of adjacent first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4** and contact each other.

Referring to FIG. 7A, portions of the four first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4** arranged in a grid configuration are illustrated. The four first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4** may be respectively attached to the substrate **101** by corresponding first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4**. Since both surfaces of each of the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4** are adhesive, the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4** may attach the four first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4** onto the substrate **101**.

Referring to FIG. 7B, when heat and pressure are applied to the plurality of first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4**, each of the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4** respectively is fluidized and starts to horizontally protrude from the lower portions of the plurality of first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4**.

At this time, although not shown in FIG. 7B, a distance between each of the plurality of first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4** and the substrate **101** may be reduced and the connection terminals **117** under the plurality of first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4** may contact corresponding upper pads **106b** (refer to FIGS. 5A and 5B) of the substrate **101**.

Referring to FIG. 7C, the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4** fluidized by heat are maintained in a fluidized state by continuously applying heat and pressure and horizontally protrude more from the lower portions of the plurality of first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4**. Furthermore, the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4** may be coalesced with adjacent first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4**.

The cross-section illustrated in FIG. 6 may correspond to the cross-section taken along the line VI-VI' of FIG. 7C.

In FIG. 7C, it is illustrated that the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4** adjacent to each other in the X direction or the Y direction are coalesced with each other. However, in some embodiments, the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4** in a diagonal direction may be coalesced with each other. In some embodiments, at a common corner of the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4**, the substrate **101** may be still exposed.

Then, the plurality of second semiconductor devices **110b**, the plurality of third semiconductor devices **110c**, and the plurality of fourth semiconductor devices **110d** may be sequentially stacked on corresponding ones of the plurality of first semiconductor devices **110a1**, **110a2**, **110a3**, and **110a4** by a similar method.

Referring to FIG. 7D, a molding resin is formed and then, is singulated along the separation line **120aSL** to obtain a separate semiconductor package. At this time, as described above, at the common corner (marked with EG) of the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4**, the substrate **101** may be exposed without being covered with the first NCFs **120a'1**, **120a'2**, **120a'3**, and **120a'4**. In such a portion, a molding resin may directly contact the substrate **101**.

Such a portion may be observed in the cross-section illustrated in FIG. 1B. That is, referring back to FIG. 1B, in

the outside of a portion in which the substrate **101** contacts the first underfill fillet **120a**, the substrate **101** may contact the molding resin **140**.

Referring to FIGS. **4** and **5c**, each of the plurality of second semiconductor devices **110b** is mounted on the corresponding ones of the plurality of first semiconductor devices **110a** under a second mounting condition in operation **S120**.

Each of the second non-conductive films may be attached to each of the plurality of second semiconductor devices **110b**. When the plurality of second semiconductor devices **110b** are completely mounted under the second mounting condition, the second non-conductive films may be changed into the second underfill fillet **120b**.

In some embodiments, the second non-conductive films are substantially the same as the first non-conductive film **120a'**. In other embodiments, the second non-conductive films have at least one physical property that is different from that of the first non-conductive film **120a'**.

In an exemplary embodiment, the second distance **hb** between the first semiconductor device **110a** and the second semiconductor device **110b** is different from the first distance **ha** between the substrate **101** and the first semiconductor device **110a**. In some embodiments, the second distance **hb** may be greater than the first distance **ha**.

Referring to FIGS. **4** and **5D**, each of the plurality of third semiconductor devices **110c** are mounted on the corresponding ones of the plurality of second semiconductor devices **110b** under a third mounting condition in operation **S130**.

Each of the third non-conductive films may be attached to each of the plurality of third semiconductor devices **110c**. When the plurality of third semiconductor devices **110c** have been mounted under the third mounting condition, the third non-conductive films may be changed into the third underfill fillet **120c**.

In some embodiments, the third non-conductive films may be substantially the same as the first non-conductive film **120a'** and/or the second non-conductive film. In other embodiments, the third non-conductive films may have at least one physical property that is different from that of at least one of the first non-conductive film **120a'** and the second non-conductive film.

In an exemplary embodiment, the third distance **hc** between the second semiconductor device **110b** and the third semiconductor device **110c** is different from at least one of the first distance **ha** and the second distance **hb**. In an exemplary embodiment, the third distance **hc** is greater than the first distance **ha**.

Referring to FIGS. **4** and **5E**, each of the plurality of fourth semiconductor devices **110d** is mounted on the corresponding ones of the plurality of third semiconductor devices **110c** under a fourth mounting condition in operation **S140**.

Each of the fourth non-conductive films may be attached to each of the plurality of fourth semiconductor devices **110d**. When the plurality of fourth semiconductor devices **110d** have been mounted under the fourth mounting condition, the fourth non-conductive films may be changed into the fourth underfill fillet **120d**.

In some embodiments, the fourth non-conductive films may be substantially the same as the first non-conductive film **120a'** to the third non-conductive film. In other embodiments, the fourth non-conductive films may have at least one physical property that is different from at least one of the first non-conductive film **120a'** to the third non-conductive film.

In an exemplary embodiment, the fourth distance **hd** between the third semiconductor device **110c** and the fourth semiconductor device **110d** is different from at least one of the first distance **ha** to the third distance **hc**. In some embodiments, the fourth distance **hd** may be greater than the first distance **ha**.

Each of the second mounting condition, the third mounting condition, and the fourth mounting condition includes a temperature, pressure, and time during which each of the second semiconductor device **110b**, the third semiconductor device **110c**, and the fourth semiconductor device **110d** is mounted.

In some embodiments, the temperature of each of the first to third mounting conditions may be about 180° C. to about 280° C. In some embodiments, the pressure of each of the first to third mounting conditions may be about 5 kPa to about 200 kPa. The time of each of the first to third mounting conditions may be about 1 second to about 100 seconds. Since correlation among the temperature, pressure, and time has been described in detail with reference to FIG. **5B**, additional description thereof will be omitted.

In the processes described with reference to FIGS. **5B** to **5E**, it is illustrated that the neighboring first underfill fillets **120a** contact each other. However, the neighboring first underfill fillets **120a** do not have to contact each other. In other embodiments, the plurality of first semiconductor devices **110a** to the fourth semiconductor devices **110d** may be mounted so that at least one of the first underfill fillets **120a** to the fourth underfill fillets **120d** contact neighboring underfill fillets.

Referring to FIGS. **4** and **5F**, the molding resin **140** is formed so as to surround side surfaces of the first semiconductor device **110a** to the fourth semiconductor device **110d** in operation **S150**.

In an exemplary embodiment, an upper surface of the fourth semiconductor device **110d** is coated with the molding resin **140**. In other embodiments, the molding resin **140** may expose the upper surface of the fourth semiconductor device **110d**. For example, a portion of the molding resin **140** covering the upper surface may be removed to expose the upper surface.

Since the molding resin **140** has been described in detail with reference to FIGS. **1A** and **1B**, a detailed description thereof will be omitted.

Referring to FIGS. **4** and **5G**, through dicing, singulation is performed to obtain the individual semiconductor package **100** in operation **S160**.

The dicing method may be performed by mechanical sawing or laser sawing. However, the inventive concept is not limited thereto.

When singulation is performed, the molding resin **140** is cut off along the separation line **120aSL** as illustrated in FIGS. **6** and **7D** so that the first underfill fillet **120a** may be exposed from the side surfaces of the molding resin **140**.

FIG. **8** is a schematic view illustrating a warpage control of the semiconductor package **100**.

Referring to FIG. **8**, when the semiconductor devices **110** are bent in the form of a smile (that is, in U-shape), the warpage property of the underfill fillets is controlled to form a cry shape (that is, in reversed U-shape) so that the warpage of the overall semiconductor package **100** may be minimized.

To the contrary, when the warpages of the semiconductor devices **110** are in the form of cry (that is, in reversed U-shape), the warpage property of the underfill fillets is

controlled to form a smile shape (that is, in U-shape) so that the warpage of the overall semiconductor package **100** may be minimized.

The temperature, pressure, and time of the above-described first to fourth mounting conditions may be determined to minimize the warpage of the semiconductor package **100**. Further, properties of the non-conductive films for forming the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** may be determined so that the warpage of the semiconductor package **100** is minimized.

By controlling the first to fourth mounting conditions, degrees to which the first to the fourth underfill fillets **120a**, **120b**, **120c**, and **120d** horizontally protrude may be controlled. Therefore, electrical connection among the semiconductor devices **110** may be ensured and the warpage of the semiconductor package **100** may be controlled.

As described above, the warpage of the semiconductor package **100** may be controlled by controlling the degrees to which the first to fourth underfill fillets **120a**, **120b**, **120c**, and **120d** horizontally protrude considering that a property of an underfill fillet horizontally protruding more is attributed more to the warpage of the semiconductor package **100**.

FIG. **9** is a side cross-sectional view illustrating a semiconductor package **1** according to an exemplary embodiment of the inventive concept.

Referring to FIG. **9**, an interposer substrate **20** is positioned on a package substrate **10** and a first sub-package **100s** and a second sub-package **200** are horizontally arranged on the interposer substrate **20**. The first sub-package **100s** and the second sub-package **200** may be encapsulated by a first molding resin **30**.

The first sub-package **100s** may be the same as the semiconductor package **100** described with reference to FIG. **1A** and a detailed description thereof will be omitted. A first sub-package substrate **101s** of the first sub-package **100s** may be the same as the substrate **101** described with reference to FIG. **1A**.

The second sub-package **200** includes a first semiconductor chip **210**. The first semiconductor chip **210** may be attached onto the interposer substrate **20** so that an active surface **212** faces the interposer substrate **20**. The first semiconductor chip **210** may be electrically connected to the interposer substrate **20** via first connection terminals **216** arranged on the active surface **212**. The first connection terminals **216** may be, for example, solder balls or bumps. A first underfill material layer **230** may be formed so as to fill a space between the second sub-package **200** and the interposer substrate **20**. The first underfill material layer **230** may be formed of, for example, epoxy resin. The first underfill material layer **230** may be a part of the first molding resin **30** formed by, for example, an MUF method. The second sub-package **200** may be, for example, a wafer level package (WLP).

The first semiconductor chip **210** may be a processor unit (e.g., a central processing unit). The first semiconductor chip **210** may be a micro-processor unit (MPU) or a graphic processor unit (GPU).

A semiconductor substrate that forms the first semiconductor chip **210** may include, for example, silicon (Si). Alternatively, the semiconductor substrate that forms the first semiconductor chip **210** may include a semiconductor element such as germanium (Ge) or a compound semiconductor such as silicon carbide (SiC), gallium arsenide (GaAs), indium arsenide (InAs), or indium phosphide (InP). Alternatively, the semiconductor substrate that forms the first semiconductor chip **210** may have a silicon on insulator (SOI) structure. For example, the semiconductor substrate

that forms the first semiconductor chip **210** may include a buried oxide layer (BOX). The semiconductor substrate that forms the first semiconductor chip **210** may include a conductive region, for example, an impurity doped well. The semiconductor substrate that forms the first semiconductor chip **210** may have various device isolation structures such as a shallow trench isolation (STI) structure.

In the first semiconductor chip **210**, a semiconductor device including various kinds of a plurality of individual devices may be formed. The plurality of individual devices may include microelectronic devices, for example, a metal-oxide-semiconductor field effect transistor (MOSFET) such as a complementary metal-insulator-semiconductor (CMOS) transistor, an image sensor such as a system large scale integration (LSI) or a CMOS imaging sensor (CIS), a micro-electro-mechanical system (MEMS), an active device, and a passive device. The plurality of individual devices may be electrically connected to the conductive region of the semiconductor substrate that forms the first semiconductor chip **210**. The semiconductor device may further include at least two of the plurality of individual devices or a conductive wiring line or a conductive plug electrically connecting the plurality of individual devices to the conductive region of a semiconductor substrate forming the first semiconductor chip **210**. In addition, the plurality of individual devices may be electrically isolated from neighboring other individual devices by an insulating layer.

The first sub-package **100s** and the second sub-package **200** may be mounted on the interposer substrate **20**.

The interposer substrate **20** may include a base substrate formed of a semiconductor material and upper pads and lower pads respectively formed on an upper surface and a lower surface of the base substrate. The base substrate may be formed of, for example, a silicon wafer or a glass substrate. In addition, an internal wiring line may be formed on the upper and/or lower surfaces of the base substrate and/or in the base substrate. In addition, in the base substrate, through vias electrically connecting the upper pads to the lower pads may be formed.

The interposer substrate **20** may be mounted on the package substrate **10** by connection terminals **25**. The connection terminals **25** may be, for example, solder balls or bumps.

The package substrate **10** may be, for example, a printed circuit board (PCB). The package substrate **10** may include a base substrate and upper pads and lower pads **16** respectively formed on an upper surface and lower surface thereof. The upper pads and lower pads **16** may be exposed by a solder resist layer with which an upper surface and a lower surface of the base substrate are covered.

The upper pads and lower pads **16** may have the same configuration as that of the upper pads **106b** and the lower pads **106a** described with reference to FIG. **1A** and a detailed description thereof will be omitted. In addition, the base substrate may have the same configuration as that of the base substrate described with reference to FIG. **1A** and detailed description thereof will be omitted.

External connection terminals **15** may be attached onto the lower surface of the package substrate **10**. The external connection terminals **15** may be attached onto, for example, the lower pads **16**. The external connection terminals **15** may be, for example, solder balls or bumps. The external connection terminals **15** may electrically connect the semiconductor package **1** to an external device.

The first molding resin **30** surrounding side surfaces of each of the first sub-package **100s** and the second sub-package **200** may be further formed on the package substrate

10. The first molding resin **30** may be formed of, for example, EMC. The first molding resin **30** may be separately formed from the molding resin of the first sub-package **100s**.

In some embodiments, as illustrated in FIG. 9, an upper surface of the first sub-package **100s** may be covered with the first molding resin **30**. However, in other embodiments, the upper surface of the first sub-package **100s** is not covered with the first molding resin **30**. For example, an upper surface of the fourth semiconductor device **110d** that is the uppermost semiconductor device among the plurality of semiconductor devices **110** included in the first sub-package **100s** is not covered with the first molding resin **30**.

In FIG. 9, an upper surface of the second sub-package **200** is illustrated as not being coplanar with the upper surface of the first sub-package **100s**. However, the upper surface of the second sub-package **200** may be coplanar with the upper surface of the first sub-package **100s**. In this case, the upper surface of the fourth semiconductor device **110d** and an upper surface of the first semiconductor chip **210** may be exposed from the first molding resin **30**.

A second molding resin **140s** surrounding side surfaces of the semiconductor devices **110** of the first sub-package **100s** may correspond to the molding resin **140** described with reference to FIG. 1A. The second molding resin **140s** may contact the first molding resin **30**. In addition, at least one of the first underfill fillet **120a** to the fourth underfill fillet **120d** may extend to an interface between the second molding resin **140s** and the first molding resin **30**. In some embodiments, the first underfill fillet **120a** to the fourth underfill fillet **120d** protrude from side surfaces of the semiconductor devices **110** toward the interface.

A heat dissipation member **40** may be disposed on top of the first sub-package **100s** and the second sub-package **200**. The heat dissipation member **40** may be, for example, a heat sink, a heat spreader, a heat pipe, or a liquid cooled cold plate.

The heat dissipation member **40** may cover the first sub-package **100s**, the second sub-package **200**, and the upper surface of the first molding resin **30**. In some embodiments, the heat dissipation member **40** may cover the upper surface of the fourth semiconductor device **110d**, the upper surface of the first semiconductor chip **210**, and the upper surface of the first molding resin **30**.

A thermal interface material (TIM) may be provided between the first sub-package **100s** and the second sub-package **200** and the heat dissipation member **40**. The TIM may be formed of an insulating material or a material capable of maintaining electrical insulation including the insulating material. The TIM may include, for example, epoxy resin. The TIM may be, for example, mineral oil, grease, gap filler putty, phase change gel, phase change material pads, or particle filled epoxy.

FIG. 10 is a side cross-sectional view illustrating a semiconductor package **1a** according to an exemplary embodiment of the inventive concept.

Since the only difference between the semiconductor package **1a** of FIG. 10 and the semiconductor package **1** of FIG. 9 lies in a configuration of the first sub-package **100s**, such a difference will be mainly described.

The first sub-package **100s** further includes a memory controller **110L** (e.g., a control circuit) between the semiconductor device **110** and the first sub-package substrate **101s**. A fifth underfill fillet **120L** is disposed between the memory controller **110L** and the first sub-package substrate **101s**.

In this case, at least one of the first to fifth underfill fillets **120a**, **120b**, **120c**, **120d**, and **120L** may extend to the

interface between the second molding resin **140s** and the first molding resin **30**. Side surfaces of the at least one of the first to fifth underfill fillets **120a**, **120b**, **120c**, **120d**, and **120L** extending to the interface between the second molding resin **140s** and the first molding resin **30** may be coplanar with side surfaces of the first sub-package substrate **101s**.

While the inventive concept has been particularly shown and described with reference to embodiments thereof, it will be understood that various changes in form and details may be made therein without departing from the spirit and scope of the disclosure.

What is claimed is:

1. A semiconductor package comprising:

a substrate;

a plurality of semiconductor devices stacked on the substrate;

a plurality of underfill fillets disposed between the plurality of semiconductor devices and between the substrate and the plurality of semiconductor devices; and a single molding resin surrounding the plurality of semiconductor devices and the plurality of underfill fillets, wherein at least one of the underfill fillets is exposed from side surfaces of the single molding resin, wherein each of the underfill fillets protrude from side surfaces of the plurality of semiconductor devices.

2. The semiconductor package of claim 1, wherein the underfill fillets comprise a first underfill fillet disposed between the substrate and the plurality of semiconductor devices, and wherein the first underfill fillet is exposed from side surfaces of the single molding resin.

3. The semiconductor package of claim 2, wherein a distance between side surfaces of the semiconductor devices and side surfaces of the single molding resin is no more than 500 μm .

4. The semiconductor package of claim 2, wherein the plurality of semiconductor devices comprise the first semiconductor device, a second semiconductor device, a third semiconductor device, and a fourth semiconductor device sequentially stacked on the first underfill fillet, wherein the plurality of underfill fillets further comprises a second underfill fillet between the first semiconductor device and the second semiconductor device, a third underfill fillet between the second semiconductor device and the third semiconductor device, and a fourth underfill fillet between the third semiconductor device and the fourth semiconductor device, and wherein at least one of the second underfill fillet, the third underfill fillet, and the fourth underfill fillet is not exposed from side surfaces of the single molding resin.

5. The semiconductor package of claim 4, wherein each of the first to fourth underfill fillets comprises inorganic particles and at least two of the first to fourth underfill fillets comprise different contents of inorganic particles.

6. The semiconductor package of claim 2, wherein a portion of the first underfill fillet exposed from the single molding resin contacts an upper surface of the substrate.

7. The semiconductor package of claim 6, wherein the substrate contacts the single molding resin at corners of the substrate.

8. A semiconductor package comprising:

a package substrate;

an interposer substrate stacked on the package substrate; a first sub-package and a second sub-package laterally arranged on the interposer substrate; and

a first molding resin surrounding side surfaces of the first sub-package and the second sub-package, wherein the first sub-package comprises:

a first sub-package substrate;

21

a plurality of memory devices stacked on the first sub-package substrate; and underfill fillets disposed between the plurality of memory devices and between the first sub-package substrate and the plurality of memory devices, and wherein at least one of the underfill fillets horizontally protrudes from side surfaces of the plurality of memory devices.

9. The semiconductor package of claim 8, wherein the first sub-package further comprises a second molding resin surrounding the plurality of memory devices, and wherein at least one of the underfill fillets extends to an interface between the first molding resin and the second molding resin.

10. The semiconductor package of claim 9, wherein the plurality of memory devices comprise a first memory device, a second memory device, a third memory device, and a fourth memory device sequentially stacked on the first sub-package substrate, and wherein the underfill fillets comprise a first underfill fillet disposed between the first sub-package substrate and the first memory device, a second underfill fillet disposed between the first memory device and the second memory device, a third underfill fillet disposed between the second memory device and the third memory device, and a fourth underfill fillet disposed between the third memory device and the fourth memory device.

11. The semiconductor package of claim 10, wherein a first underfill fillet among the underfill fillets horizontally protrudes most.

12. The semiconductor package of claim 10, wherein the underfill fillets protrude from side surfaces of the plurality of memory devices toward side surfaces of the second molding resin.

13. The semiconductor package of claim 10, wherein at least two of the first to fourth underfill fillets comprise different compositions of inorganic particles.

14. The semiconductor package of claim 10, wherein at least two of the first to fourth underfill fillets have different coefficients of thermal expansion.

22

15. The semiconductor package of claim 10, wherein at least two of the first to fourth underfill fillets contact each other with an interface interposed therebetween.

16. The semiconductor package of claim 9, wherein side surfaces of the at least one of the underfill fillets extending to an interface between the first molding resin and the second molding resin are coplanar with side surfaces of the first sub-package substrate.

17. The semiconductor package of claim 8, wherein the first sub-package further comprises a memory controller chip disposed between the first sub-package substrate and the plurality of memory devices.

18. The semiconductor package of claim 17, wherein the plurality of memory devices are electrically connected to each other by through silicon vias (TSV).

19. The semiconductor package of claim 8, wherein at least one of the underfill fillets horizontally protrudes from the side surfaces of the plurality of memory devices by about 200 μm to about 500 μm.

20. A semiconductor package comprising:
 a package substrate;
 a plurality of semiconductor devices stacked on the package substrate;
 a plurality of underfill fillets disposed between the plurality of semiconductor devices and between the package substrate and the plurality of semiconductor devices; and

a molding resin surrounding the plurality of semiconductor devices, wherein each of the underfill fillets protrudes to an outside of side surfaces of the plurality of semiconductor devices,

wherein at least one of the underfill fillets is exposed from side surfaces of the molding resin and side surfaces of the underfill fillet exposed from the side surfaces of the molding resin among the underfill fillets are coplanar with the side surfaces of the molding resin.

21. The semiconductor package of claim 20, wherein a distance between side surfaces of the plurality of semiconductor devices and side surfaces of the molding resin is no more than 500 μm.

* * * * *